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Demonstration and Validation of Reactive Vitreous Coatings to Prevent Corrosion of Steel Fixtures Attached to Masonry Walls

Final Report on Project F10-AR12

Steven C. Sweeney, Christopher Olaes, and Darrell Skinner December 2016

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Demonstration and Validation of Reactive Vitreous Coatings to Prevent Corrosion of Steel Fixtures Attached to Masonry Walls

Final Report on Project F10-AR12

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Final report

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Under Project F10-AR12, "Use of Reactive Vitreous Coatings on Steel Fixtures for Masonry Wall to Prevent Corrosion at Fort Stewart, GA"

Abstract

Masonry block and brick wall veneer construction, widely used on military installations, is subject to rapid deterioration when the ferrous hardware tying brick veneer to substrate corrodes prematurely. Corrosion of veneer-anchor hardware can compromise structural integrity and cause fracture and spalling of masonry materials. Because these building ties are concealed beneath the veneer, corrosion can proceed undetected until structural damage occurs. A new reactive silicate material that can be bonded to steel hardware with a layer of vitreous enamel, developed by the U.S. Army Engineer Research and Development Center, was evaluated for corrosion-protection performance in a demonstration project at Fort Stewart, GA. When fractured, this coating produces a self-healing reaction by formation of silicate hydration products that passivate any exposed steel surface. Steel anchors were coated with the vitreous enamel and then installed in sections of damaged brick veneer on buildings needing rehabilitation. Brick/block coupons were also fabricated using these anchors for exposure and ASTM E754 pullout-strength testing.

Results show that the enamel-coated ties were more corrosion resistant than both bare steel and galvanized ties used in the exposure specimens. Issues with coating coverage and flaking were noted, and implementation caveats are offered. The project return on investment was 3.31.

Contents

Figures and Tables

Figures

Tables

Preface

This study was conducted for the Office of the Secretary of Defense (OSD) under Corrosion Prevention and Control Program Project F10-AR12, “Use of Reactive Vitreous Coatings on Steel Fixtures for Masonry Wall to Prevent Corrosion at Fort Stewart, GA.” The proponent was the U.S. Army Office of the Assistant Chief of Staff for Installation Management (ACSIM), and the stakeholder was the U.S. Army Installation Management Command (IMCOM). The technical monitors were Daniel J. Dunmire (OUSD(AT&L)), Bernie Rodriguez (IMPW-FM), and Valerie D. Hines (DAIM-ODF).

The work was performed by the Materials Branch of the Facilities Division (CEERD-CFM), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Vicki Van Blaricum was Chief, CEERD-CFM; Donald K. Hicks was Chief, CEERD-CF and Kurt Kinnevan, CEERD-CZT was the Technical Director for Adaptive and Resilient Installations. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Ilker Adiguzel.

John B McCormick (CESAW-ECP-CJ), Civil Engineer at Fort Stewart, GA, is gratefully acknowledged for his support and assistance in this project.

The Commander of ERDC was COL Bryan S. Green and the Director was Dr. Jeffery P. Holland.

Unit Conversion Factors

Multiply	By	To Obtain
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
inches	0.0254	meters
inch-pounds (force)	0.1129848	newton meters
mils	0.0254	millimeters
pounds (force)	4.448222	newtons
pounds (force) per foot	14.59390	newtons per meter
pounds (force) per in.	175.1268	newtons per meter
pounds (force) per square foot	47.88026	pascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per cubic in.	2.757990 E+04	kilograms per cubic meter
pounds (mass) per square foot	4.882428	kilograms per square meter
square feet	0.09290304	square meters

1 Introduction

1.1 Problem statement

Masonry block and brick wall veneer construction is commonly used for administrative and residential construction on Department of Defense (DoD) installations. Many such structures use two-piece steel wall anchors, each consisting of a pintle and an eye, embedded in the mortar to anchor courses of brick masonry to other structural elements in the building. Corrosion of these ties degrades bonding between the mortar and the steel, , and this can cause the loss of structural continuity within the wall. Failures in structural connection of this type become visible when brick/block and mortar spalls or crumbles away from the wall. Because the steel fixtures are covered with mortar and hidden from view during construction, corrosion can proceed undetected until serious damage has occurred.

There is currently no simple solution to the deterioration of reinforcement steel embedded in concrete or masonry. Industry-standard epoxy coatings may crack or delaminate from the steel in as little as five years and concrete additives have not yet been shown to be effective in preventing the corrosion of masonry-embedded steel. Researchers at the U.S. Army Engineer Research and Development Center (ERDC) previously developed a new reactive silicate material that can be bonded to steel reinforcement bars with a layer of vitreous enamel (Morefield et al. 2008). The vitreous enamel coating contains a blend of a hydraulically reactive silicate cement with a glass enameling frit that is fused to steel. Research has shown that when Portland cement is used in the vitreous formulation, the hydration reaction that occurs in cement paste is also observed in the cement component of the coating. If the coating fractures, a self-healing reaction can result through the creation of calcium silicate hydration products (Morefield et al. 2008). Experimental results have indicated that after only seven days of curing, the chemical bond that forms between coated steel elements and concrete is typically two to three times stronger than it is for bare steel, while also protecting the steel from corrosion processes initiated by the intrusion of moisture and chlorides or other chemicals (Moser et al. 2010). The technology was awarded a U.S. patent in 2014 (Day et al. 2014).

In order to evaluate the potential applicability of this technology to brick/block masonry construction, a Corrosion Prevention and Control Program demonstration/validation (dem/val) project was funded to fabricate, install, and assess the performance of enamel-coated steel anchors in existing buildings that require rehabilitation due to corrosion-related brick veneer and structural degradation.

1.2 Objective

The objective of this project was to install new steel hardware coated with the patented calcium-silicate enamel as part of scheduled brick/block facility rehabilitation at Fort Stewart, GA; visually monitor corrosion effects and performance; and measure the strength of masonry specimens representing the demonstrated structural system.

1.3 Approach

The project team identified several buildings at Fort Stewart, GA, that were damaged due to corroded wall ties and scheduled for replacement of most of their brick veneer. The team selected Buildings 632 and 635 for the demonstration. The brick panels targeted for replacement on these buildings displayed visible evidence of failure in the form of cracking, broken bricks, displaced mortar, and wall ties that had broken free and were visibly protruding from the panels.

The project was coordinated with the Fort Stewart Department of Public Works, which retained a contractor to refurbish the failing brick veneers. This contractor was also responsible for providing the enamel-coated wall ties. All of the brick panels replaced on Buildings 632 and 635 incorporated these fuse-bonded, enamel-coated wall ties instead of standard steel ties. These ties were subsequently inspected at various intervals using a borescope at inspection points built into the structures during repair.

In addition, test samples were made at the project site with the same materials used in the repair. These samples were then exposed to the elements at both Fort Stewart and at test racks constructed at an oceanfront research site at Duck, NC. These samples were removed at various times to inspect for corrosion and test the ties for pull-out strength.

1.4 Metrics

The primary means of evaluating technology performance was visual inspection of the wall ties for any corrosion activity. The external wall panels, installed vitreous brick ties, and exposed coupons were inspected at quarterly intervals. Twenty-one inspection points on Buildings 632 and 635 were selected for monitoring. During masonry rehabilitation, the inspection points were fitted with flexible plastic tubing behind the brick veneer to facilitate the use of a fiber-optic borescope device in performing the inspections.

Additionally, 12 brick coupons were fabricated for exposure testing at Fort Stewart and at the Field Research Facility (FRF) located at Duck, NC. Mortar joint strength of the coupons was tracked and tested in accordance with ASTM E754-80 (2006), *Standard Test Method for Pullout Resistance of Ties and Anchors Embedded in Masonry Mortar Joints*.

2 Technical Investigation

2.1 Project overview

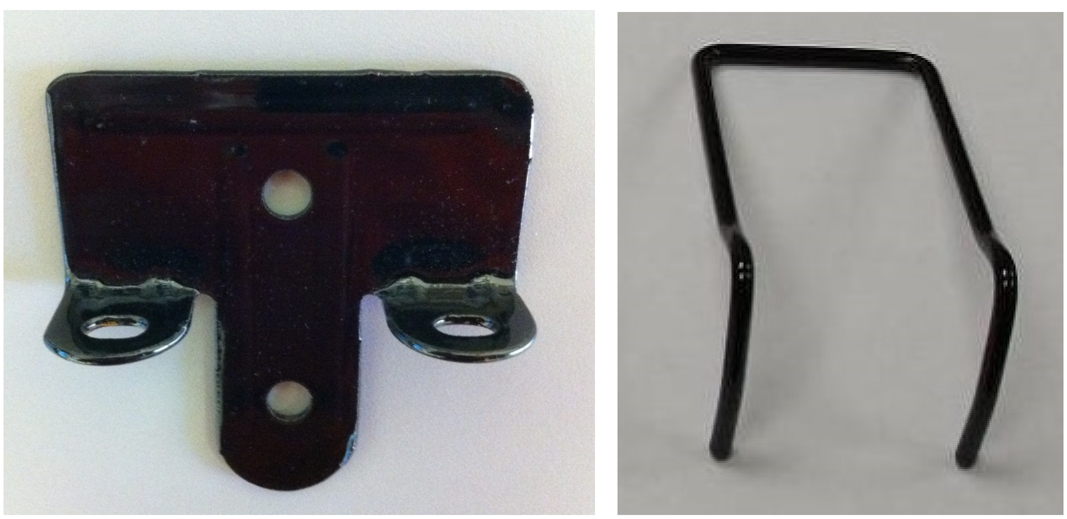
This demonstration involved selecting two buildings that totaled approximately 6,200 sq ft of masonry requiring replacement. The subject buildings had multiple panels of masonry work that displayed visible evidence of failure in the form of fractured/crumbling brick, corroded reinforcing wire, and displaced mortar joints as shown in Figure 1 and Figure 2.

Figure 1. Exterior view of Building 632 brick veneer construction.

For the purposes of this demonstration 2,500 two-piece steel wall ties, each consisting of double-eye wall plates and 5 by 2 in. rectangular wire pintles of 3/16 in. diameter were procured (Figure 3). This hardware was sent to Pro Perma Engineered Coatings in Rolla, MO, for application of the vitreous enamel coating. After coating, the materials were shipped to Fort Stewart for installation.

Figure 2. Failed masonry joints, showing spalled bricks.

Figure 3. Vitreous-coated double-eye tie component (left) and pintle (right).



2.2 Installation of the technology

The demonstration buildings were cordoned off, protective barriers were installed to limit pedestrian traffic, and scaffolding was erected as required, as shown in Figure 4. Figure 5 depicts the selected panels that were stripped of hardware, moisture barrier, and coatings until the bare cinder-block substructure was exposed.

Figure 4. Scaffolding erected for project.

Figure 5. Selected panels stripped to bare walls.

To begin the rehabilitation of the wall panels, a waterproof adhesive was applied to the concrete block (Figure 6). The adhesive/sealant was applied liberally to each wall panel using a paint roller system to ensure an effective coating for the installation of rubber waterproof sheathing. Figure 7 shows application of the sheathing.

Figure 6. Application of adhesive.

Figure 7. Application of the rubber sheathing.

Chalk lines applied to the wall panels provided straight and level courses and proper spacing for the wall ties to be anchored (Figure 8). A hammer drill was used to create the holes for the wall tie anchors along the chalk lines. After the holes were drilled, the anchor plate and fasteners were installed using two, ¼ in. diameter hammer-drive pin anchors (Figure 9).

Figure 8. Installed double-eye component with chalk line for alignment.

Figure 9. Drilling a pilot hole for a double-eye wall tie component.

Upon installation of the anchor plates on the wall panels (Figure 10), a 1 in. layer of insulating foam board was installed over the entire wall panel (Figure 11). A small portion of the foam was cut out to facilitate installing the eyes (Figure 12). Figure 13 shows a section of installed pintles.

Figure 10. Installation of a double-eye wall tie component.

Figure 11. Installation of foam board insulation.

Figure 12. Coated double eye component with pintle attached.

Figure 13. Installed pintles protruding through foam insulation.

At designated sites on select wall panels, a 5/8 in. plastic tubing was installed to provide the guide for the borescope camera inspections (Figure 14). In each of these wall panels, three wall ties were selected as inspection points. Guide tubes were secured to the foam insulation board, with the interior ends of the tubes being turned down to prevent debris from falling into the tube and obstructing it. The brick masons then laid mortar and brick in the customary manner for anchored brick veneer construction (Figure 15).

Figure 14. Plastic tubing for borescope inspection.

Figure 15. View showing brickwork and mortar adjacent to tubes and tie.

2.3 Technology operation and monitoring

Visual inspections were facilitated by the inspection points installed in select wall panels during construction. Immediately after installation, a visual inspection of the exterior walls of Buildings 632 and 635 was completed. The performance of the vitreous coated wall ties was monitored for 18 months. Borescope inspections were performed one month after the installation and at three-month intervals. A final inspection was performed one month prior to the end of the monitoring period.

This demonstration also included the construction of 50 masonry coupons to be used in destructive exposure testing (see Figure 16 and Figure 17). The vitreous-ceramic coated pintle was installed in 15 of the test coupons, and a conventional galvanized steel pintle was installed in 15 other coupons. The remaining 20 specimens were comparison coupons, each built with an uncoated steel pintle, a galvanized steel pintle, and an enamel-coated steel pintle.

Figure 16. Production of ASTM E754 coupons.

Figure 17. Production of comparison coupons.

The coupons were transported to two different geographic locations for exposure. Twenty-two of the coupons were set up in a USACE test yard at Fort Stewart and twenty-two were moved to the FRF at Duck, NC, for exposure to a high-chloride coastal environment (see Figure 18 and Figure

19). The remaining six coupons were sent to a testing facility for ASTM E754 testing after completing the required seven-day cure cycle.

Baseline data were acquired using a borescope camera in video mode to establish the condition of the pintles at the start of the inspection period. Over the course of the next two years, photos and videos will be updated periodically to note any detectable corrosion. At twelve-month intervals, exposure coupons were retrieved from the exposure sites and tested in accordance with ASTM E754.

Figure 18. Fort Stewart coupon test rack.

Figure 19. Duck, NC, coupon test rack.

3 Discussion

3.1 Results

The overall observation is that, to date, the wall ties have performed as expected. No failure of the wall panel or individual mortar joints has occurred, and no evidence of corrosion has been detected in the wall ties.

3.1.1 ASTM E754 pullout testing

The results of the initial ASTM E754 testing of the coupons is shown in Table 1. The average peak load before failure of the vitreous coated ties was 2,174 lb, and the average load before failure of the galvanized ties was 1,749 lb. After 12 months of exposure, the average peak load before failure of the vitreous coated ties was 2,251 lb, and the average load before failure of the galvanized ties was 1,901 lb (Table 2). The vitreous-coated ties had 18.4% higher pullout strength at that time compared to the galvanized ties. After 18 months of exposure, the average load before failure for the vitreous-coated ties was essentially the same as in the 12 month tests (2,227 lb). At that same time, the galvanized ties had a pullout strength of 1,642 lb (Table 3), a 13.6% reduction in strength. These test results show that the vitreous-coated ties maintained their pullout strength while the pullout strength of the galvanized specimens degraded during the performance period.

Table 1. ASTM-E754 initial results for control samples, March 2011.

Sample ID	Peak Load (lb)	Peak Displacement (in.)	Failure Type
V 1	2,109	0.7320	Mortar joint failure
V 2	2,103	0.7520	Metal pullout failure
V 3	2,310	0.7470	Mortar joint shear
Average	**2,174**	**0.7437**	**NA**
G 1	1,873	0.5210	One-sided metal pullout failure
G 2	1,716	0.5050	One-sided metal pullout failure
G 3	1,569	0.5100	One-sided metal pullout failure
Average	**1,749**	**0.5120**	**NA**

Table 2. ASTM-E-754 results of sample with approximately 12 months of exposure, February 2012.

Sample ID	Peak Load (lb)	Displacement at Peak Load (in.)	Failure Type
VST 1	1,911	0.1940	One-sided metal pullout failure
VST 2*	1,146	0.1825	Mortar joint shear
VST 3	2,221	0.5015	One-sided metal pullout failure
Average	**1,760**	**0.2927**	**NA**
GST 1	1,959	0.1038	One-sided metal pullout failure
GST 2	1,436	0.1995	Double sided metal pullout failure
GST 3	1,487	0.0818	Mortar joint shear
Average	**1,627**	**0.1284**	**NA**
VNC 1	2,258	0.6208	One-sided metal pullout failure
VNC 2	2,235	0.3443	One-sided metal pullout failure
VNC 3	2,261	0.3398	One-sided metal pullout failure
Average	**2,251**	**0.4350**	**NA**
GNC 1	2,962	0.1960	One-sided metal pullout failure
GNC 2	1,479	0.1338	Mortar joint shear
GNC 3	1,261	0.1478	One-sided metal pullout failure
Average	**1,901**	**0.1592**	**NA**

Table 3. ASTM-E-754 results of sample with approximately 18 months of exposure, August 2012.

Sample ID	Peak Load (lb)	Displacement at Peak Load (in.)	Failure Type
VST 4	2,132	0.4715	One-sided metal pullout failure
VST 5	2,252	0.6225	One-sided metal pullout failure
VST 6	2,235	0.7573	One-sided metal pullout failure
Average	**2,206**	**0.6171**	**NA**
GST 4	1,575	0.2970	One-sided metal pullout failure
GST 5	1,658	0.0930	Double sided metal pullout failure
GST 6	2,487	0.3103	Double sided metal pullout failure
Average	**1,907**	**0.2334**	**NA**
VNC 4	2,238	0.4333	One-sided metal pullout failure
VNC 5	2,203	0.7560	One-sided metal pullout failure
VNC 6	2,240	0.6395	One-sided metal pullout failure
Average	**2,227**	**0.6096**	**NA**
GNC 4	1,391	0.3703	One-sided metal pullout failure
GNC 5	1,752	0.2593	One-sided metal pullout failure
GNC 6	1,782	0.2468	One-sided metal pullout failure
Average	**1,642**	**0.2921**	**NA**

3.1.2 Borescope visual inspections

Borescope inspections were completed every 3 months for a period of 18 months after installation. Figure 20 – Figure 27 are images from the final inspection completed in August 2012, and they include eye and pintle components that show the most evidence of corrosion from each inspection location. Individual reports from each inspection are listed in Appendix C. Corrosion was primarily found on the rounded edges of the eye components. The rounded edges are the most susceptible coating imperfections, which was the cause for the corrosion found on items tested. The pintles showed little to no corrosion in all locations. It was also observed that the components experiencing the most corrosion were in locations with the least exposure to sunlight, suggesting that prolonged moisture retention in the masonry may have been a factor.

Figure 20. Borescope inspection of a vitreous coated wall tie after 18 months of exposure in Building 635 location 2-2.

Figure 21 Borescope inspection of a vitreous coated wall tie after 18 months of exposure in Building 635 location 1-1.

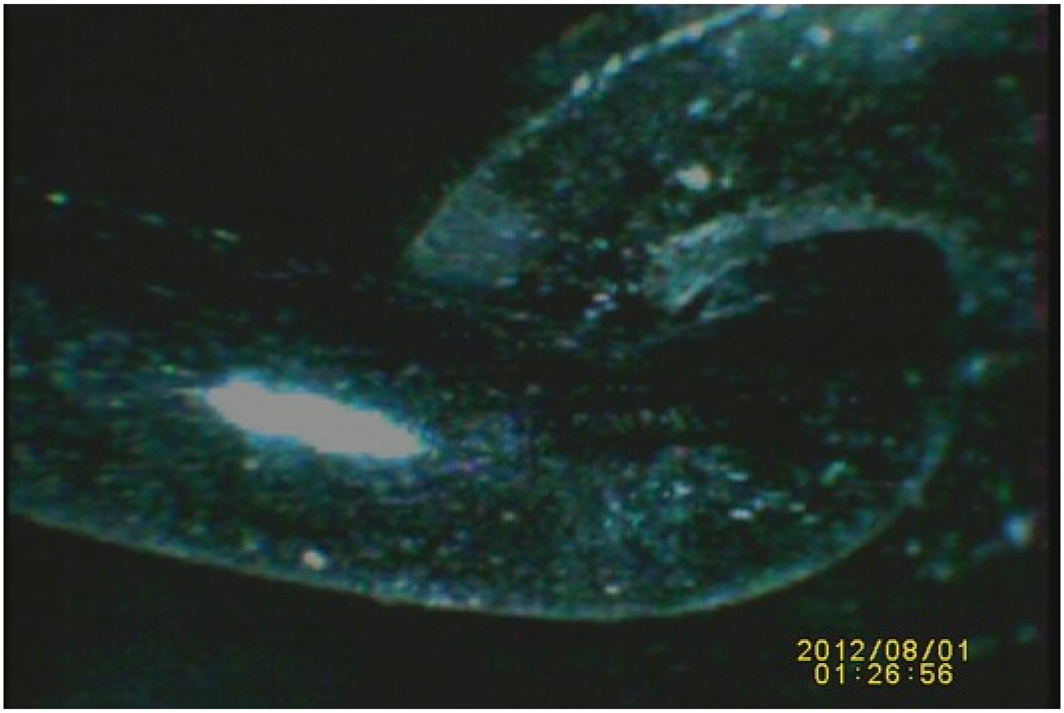


Figure 22 Borescope inspection of a vitreous coated wall tie after 18 months of exposure in Building 635 location 3-3.

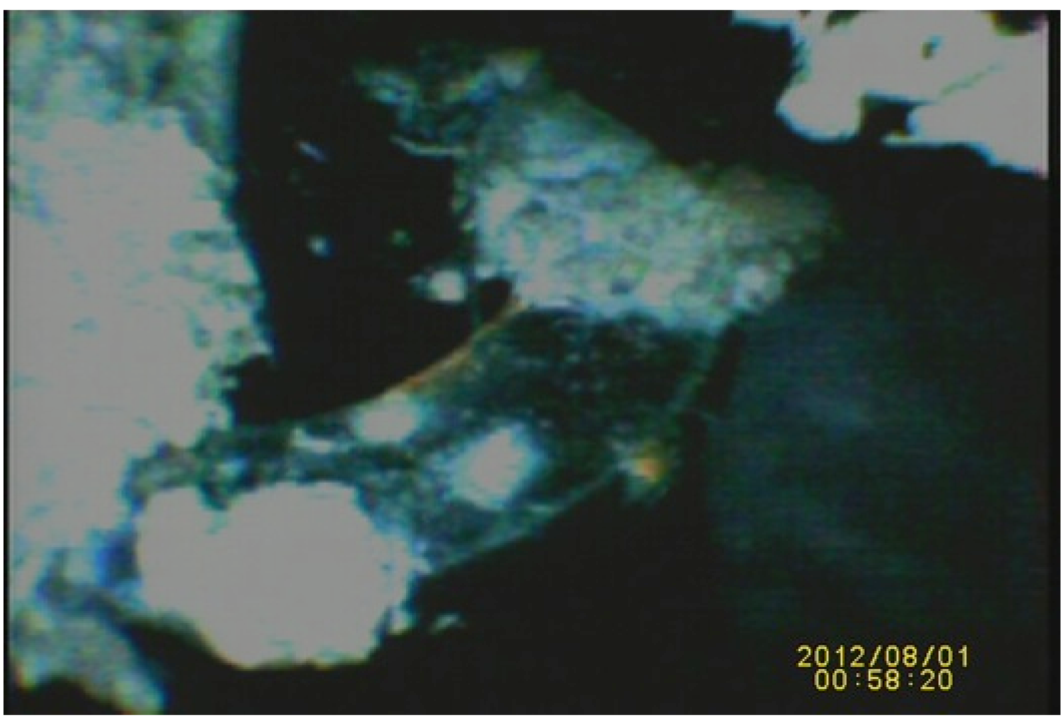


Figure 23. Borescope inspection of a vitreous coated wall tie after 18 months of exposure in Building 635 location 4-1.

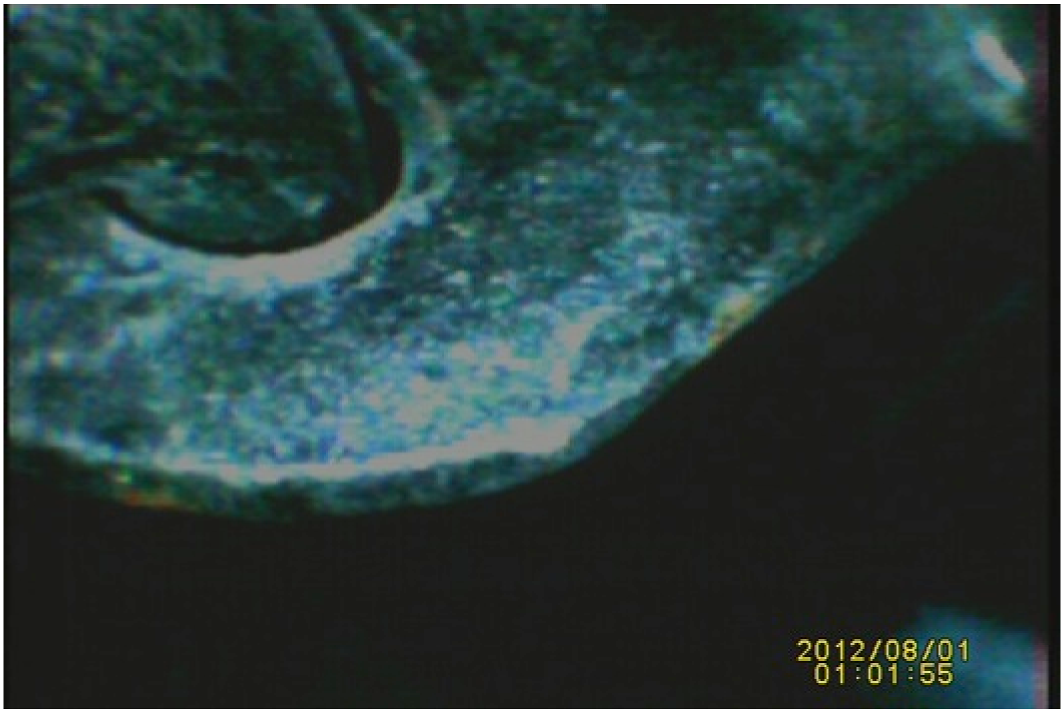


Figure 24. Borescope inspection of a vitreous coated wall tie after 18 months of exposure in Building 632 location 2-1.

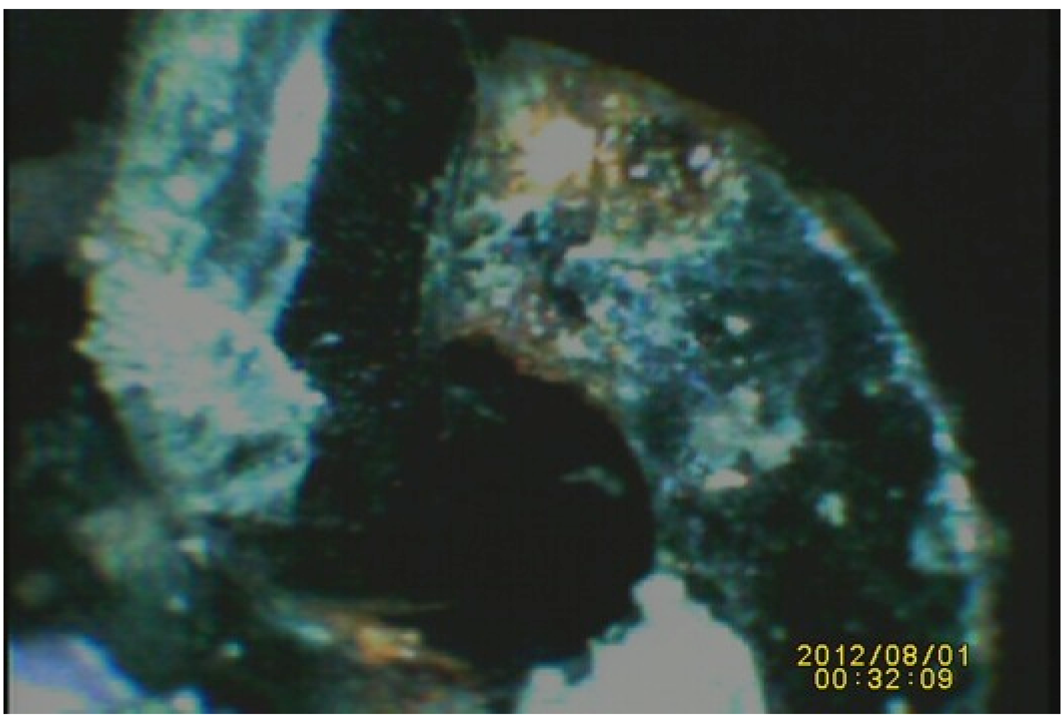


Figure 25. Borescope inspection of a vitreous coated wall tie after 18 months of exposure in Building 632 location 3-1.

Figure 26. Borescope inspection of a vitreous coated wall tie after 18 months of exposure in Building 632 location 3-1.

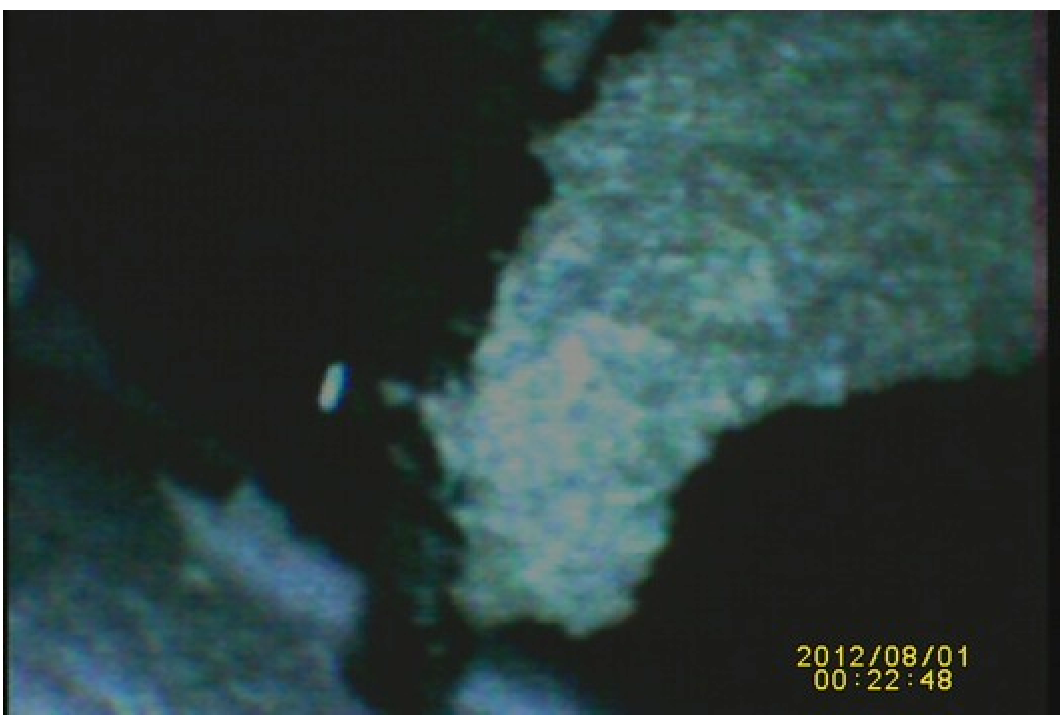
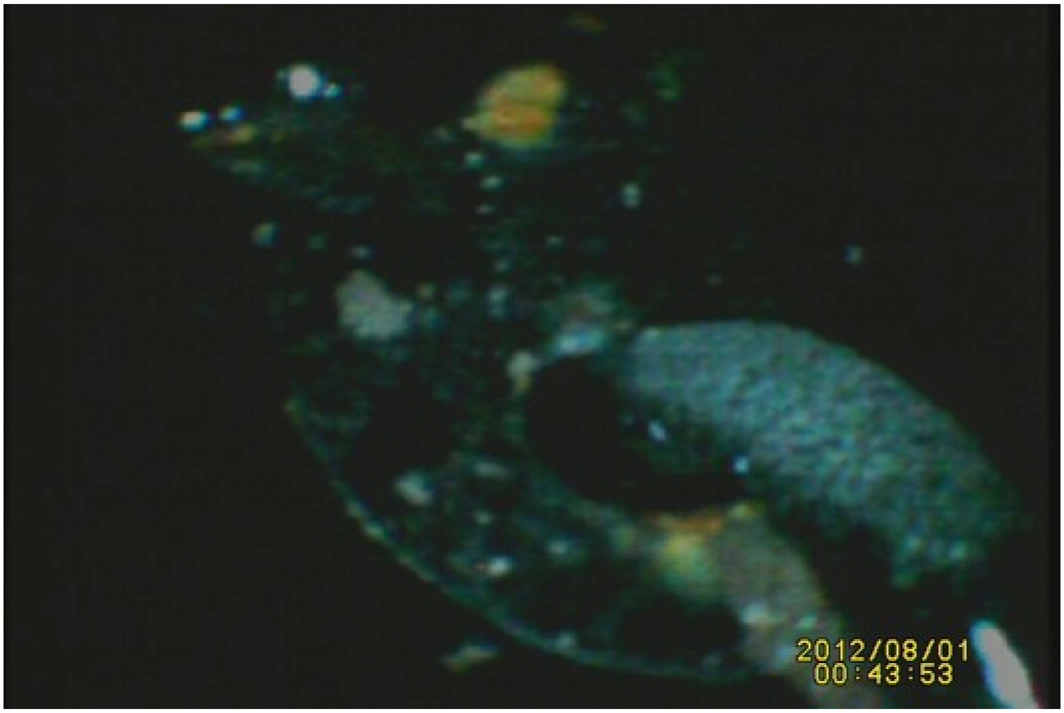


Figure 27. Borescope inspection of a vitreous coated wall tie after 18 months of exposure in Building 632 location 4-2.



3.1.3 Destructive inspection of coupons

Visual inspections of the brick coupon were completed every 3 months for a period of 18 months after installation. Figure 28 – Figure 37 are images from the final inspection completed in August 2012. Individual reports from each inspection are listed in Appendix C. The brick coupons were broken apart and the mortar was removed from the pintles. The surface area of the standard steel and galvanized pintle that was outside the mortar was 100% covered in rust within 9 months of exposure. The vitreous coated pintle only showed signs of corrosion at the tip of the pintle as shown in Figure 30. The geometry of the tip of the pintle is subject to inadequate coating during application and is the cause of the corrosion. Within 18 months, rust was beginning to form throughout the width of the brick coupon on the standard and galvanized coupons. The vitreous coated coupons did not show any visual signs of corrosion in the interior of the brick coupons.

Figure 28. Destructive inspection of prism interior with galvanized pintle after 18 months of exposure at Fort Stewart.

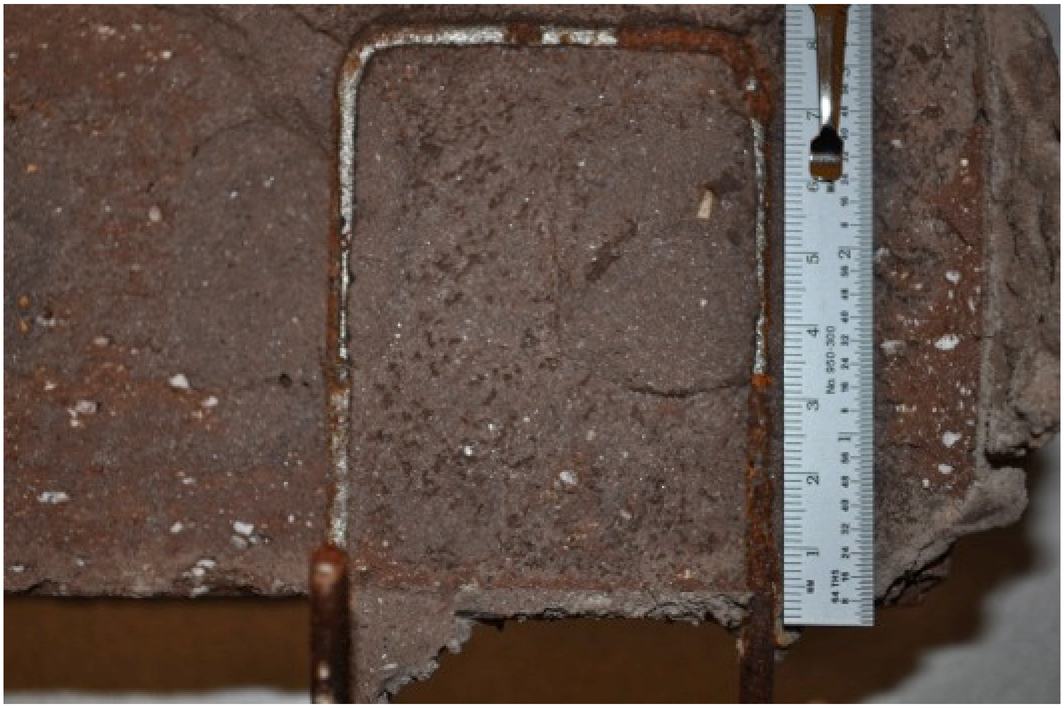


Figure 29. Inspection of the exterior part of the galvanized pintle after 18 months of exposure at Fort Stewart, GA.

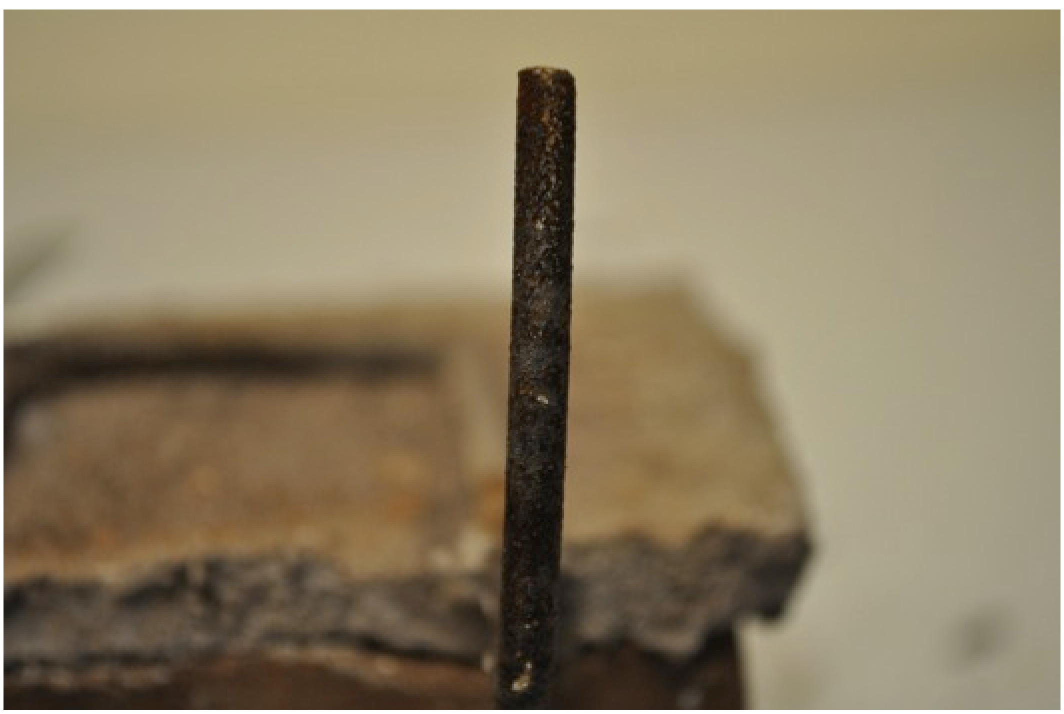


Figure 30. Inspection of the exterior tip of the galvanized pintle after 18 months of exposure at Fort Stewart, GA.

Figure 31. Inspection of the exterior part of the vitreous coated pintle after 18 months of exposure at Fort Stewart, GA.

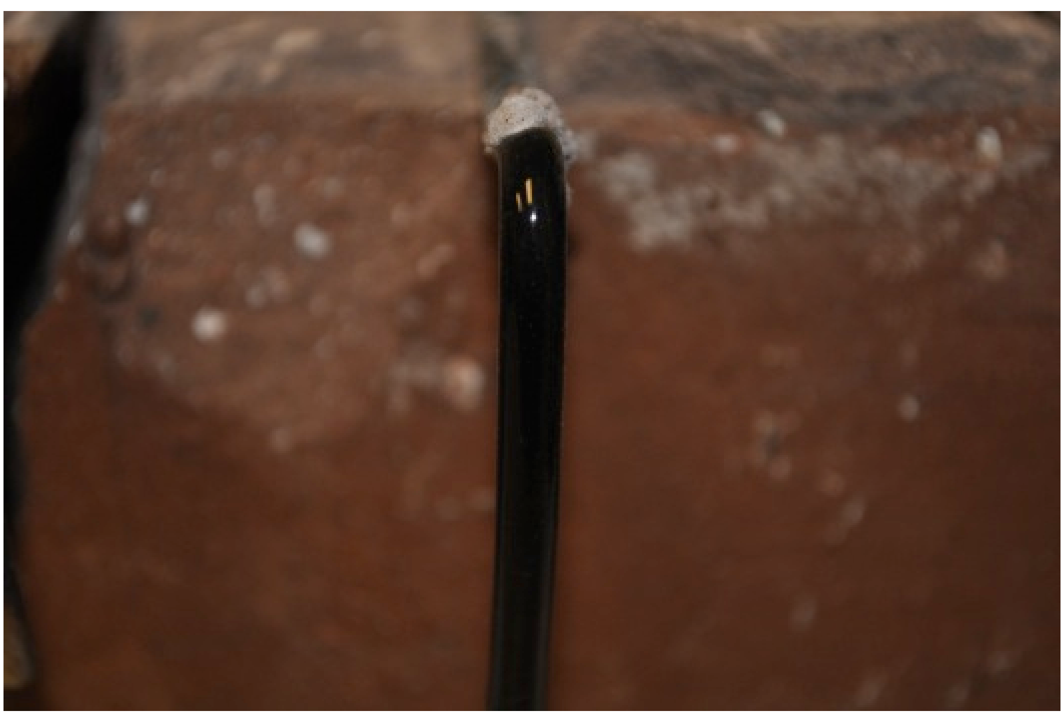


Figure 32. Destructive inspection of the interior of a vitreous coated pintle after 18 months of exposure at Fort Stewart, GA.

Figure 33. Inspection of the exterior part of the standard steel pintle after 18 months of exposure at Duck, NC.

Figure 34. Inspection of the exterior part of the standard steel (left) and galvanized (right) pintle after 18 months of exposure at Duck, NC.

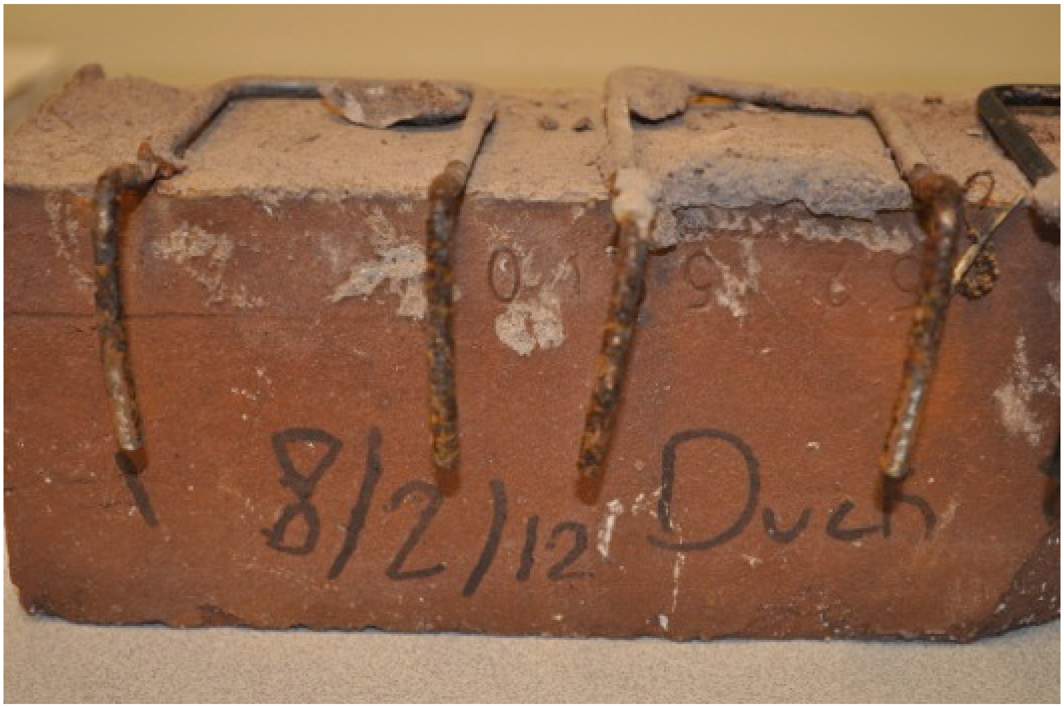


Figure 35. Inspection of the exterior part of the galvanized (left) and vitreous coated (right) pintle after 18 months of exposure at Duck, NC.

Figure 36. Destructive inspection of the interior of a standard steel (left) and galvanized (right) pintle after 18 months of exposure at Duck, NC.

Figure 37. Destructive inspection of the interior of a galvanized (left) and vitreous coated (right) pintle after 18 months of exposure at Duck, NC.

3.2 Coating material characteristics and coverage

Inspection results indicate that the demonstrated coating is very brittle, like a typical ceramic or glass material. Therefore, the coating is vulnerable to fracture when the treated hardware is bent or subject to sharp impact. Although conventional steel ties and pintles tolerate bending adjustments and impacts related to shipping, handling, and installation, the coating on the demonstrated enameled hardware is subject to damage from such stresses. The wall ties in particular are subject to sharp impacts associated with the installation process, which uses hammer-driven pin anchors as described in section 2.2, Figure 10; the impact of hammering can potentially cause damage to the coating.

Destructive inspection of some of the 20 comparison coupons (i.e., those containing one bare steel, one galvanized steel, and one enamel-coated steel tie assembly) revealed galvanized pintles that were corroding faster than individual galvanized ones in specimens earmarked for ASTM E754 testing, such as the one shown in Figure 38.

Figure 38. Solo galvanized pintle in an ASTM E754 brick coupon at Fort Stewart, GA.

It was determined that the presence of the uncoated steel pintle inside the same coupon as the galvanized one created a corrosion cell when moisture was present in the mortar to serve as an electrolyte and conductor. The

zinc coating of the galvanized pintle had begun to sacrifice itself to protect exposed steel in both pintles. Corrosion-cell current was confirmed by connecting a multimeter to both materials. Because the vitreous enamel coating is an insulating material, no current should have been able to move between the galvanized pintle and the coated one as observed. To verify that corrosion current was affecting the coated hardware, a tip was cut off and voltage measurement was taken between the exposed substrate and the standard steel pintle; the recorded voltage was similar to the current between the bare steel and galvanized specimens, suggesting the presence of a break in the vitreous coating undetected through visual inspection.

3.3 Lessons learned

The vitreous coating has a very high gloss and makes borescope inspection difficult. The light at the end of the borescope reflects off the coating and back at the camera lens, causing glare and focusing difficulties. Several types of borescope tips were used to diminish this effect; however, none were able to completely mitigate the reflection. Consequently, many photographs were out of focus due to a lack of light and incorrect focal length; others were degraded by glare from the vitreous reflective surfaces. Since this inspection method is potentially beneficial for other corrosion prevention and control studies or applications, prospective users should investigate the availability of a polarizing filter or similar optical or digital methods that could minimize or eliminate the specular glare that degraded the visual data in this project.

4 Economic Summary

4.1 Costs and assumptions

The total cost of this project amounted to about $400,000. A rough breakdown of project expenses is shown in Table 4, and the field demonstration costs are shown in Table 5.

Table 4. Summary of expenditures for CPC Project F10-AR12.

Description	Amount, $K
Labor	166.3
Contracts	188.7
Travel	20
Reporting	20
Air Force and Navy participation	5
Total	400

Table 5. Cost breakdown for performing field demonstration and validation.

Description	Amount, $K
Labor for project management and execution	126.5
Travel for project management	19.9
Cost for wall ties (5000)	2.3
Cost for coating wall ties (5000)	5.0
Cost for evaluation and report	35.0
Total	188.7

Standard galvanized wall ties have become common in the installation of brick veneers. Although galvanized steel is effective at preventing corrosion, the life cycle in this application is expected to be only 120 months. Hardware coated in a vitreous enamel is expected to last three to five times longer than traditional galvanized wall ties.

To calculate the return on investment (ROI), it is assumed that the DoD commonly builds brick veneer structures for use as administrative and residential construction. Brick veneer construction typically uses metal ties to connect the brick to the structural frame. Brick veneer construction typically costs $14.00 per sq ft, and the metal hardware (i.e., ties, flashing, etc.) typically accounts for 3% of the installation and materials cost. Applying the vitreous enamel coating to standard metal hardware will increase

that cost to 4.5% of the total, meaning that the cost of coating ties for a single average building would be $0.010/sq ft of brick veneer. An average administrative or residential building requires 39,200 sq ft of brick veneer. It is assumed that normal ties would deteriorate in 10 years to the point of requiring repair, and that repair of the normal tie system would be equal to original construction costs (assumed to be $275,000). Properly coated ties are assumed to last for 30 years. For the purpose of this ROI calculation, ten total buildings on the installation are assumed to be repaired using these wall ties over the next ten years.

4.2 Projected return on investment (ROI)

The total investment for this project was $400,000. The return on investment is achieved by reducing the need for repairs owing to the corrosion resistance of the vitreous-coated ties. The ROI was calculated in accordance with U.S. Office of Management and Budget Circular No. A-94 (1992). Over the specified 30-year analysis period (Table 6), the calculated ROI was 3.31.

Table 6. Return on investment calculations for Project F10-AR12.

Return on Investment Calculation

Investment Required			400
Return on Investment Ratio	3.31	Percent	331%
Net Present Value of Costs and Benefits/Savings	1,832	3,155	1,323

A Future Year	B Baseline Costs	C Baseline Benefits/Savings	D New System Costs	E New System Benefits/Savings	F Present Value of Costs	G Present Value of Savings	H Total Present Value
1							
2	275		279		244	240	-4
3	275		279		228	224	-3
4	275		279		213	210	-3
5	275		279		199	196	-3
6	275		279		186	183	-3
7	275		279		174	171	-3
8	275		279		162	160	-2
9	275		279		152	150	-2
10	275		279		142	140	-2
11	275		279		133	131	-2
12	275					122	122
13	275					114	114
14	275					107	107
15	275					100	100
16	275					93	93
17	275					87	87
18	275					81	81
19	275					76	76
20	275					71	71
21	275					66	66
22	275					62	62
23	275					58	58
24	275					54	54
25	275					51	51
26	275					47	47
27	275					44	44
28	275					41	41
29	275					39	39
30	275					36	36

5 Conclusions and Recommendations

5.1 Conclusions

The demonstrated vitreous enamel coating provides a method to mitigate the potential for corrosion and extend the service life of wall ties used in brick-veneer masonry construction, thereby reducing the need for costly periodic repairs caused by corroded wall-tie hardware. The coating applied to the pintle-and-eye type wall ties used in this project proved to be more resistant to corrosion than both stock steel and galvanized steel wall ties. However, the vitreous coating is subject to flaking and cracking, and the coating of the complex geometry—specifically at the ends of the pintle wire—was found to be inconsistent, allowing spot corrosion to occur. If used, all coated pieces should be closely inspected before installation, and the pintles should not be bent or impacted during installation.

In several cases there also was inadequate coverage on geometric shapes with rounded edges. The borescope inspections of the installed coated pintles showed that some rounded edges were susceptible to corrosion. As seen in the exposure coupons, the tips of the pintles also were a weak area of the coating, confirming the borescope inspections.

The ASTM E754 testing was not able to validate any increase in the bond strength of the masonry specimen through the use of the vitreous coating, but the results showed that the coating enhances the pullout strength over galvanized pintles.

The exposure coupon experiment designed to determine corrosion rates of each type of pintle was flawed. A galvanic corrosion cell was created inadvertently when the dissimilar metals of the four pintles were placed in the same mortar on a single brick coupon. As a result, the destructive coupons did not provide an individual performance comparison of corrosion resistance of each pintle type. None the less, the coupons verified that the vitreous coating holds up significantly longer than traditional coatings.

The economic analysis projects that the vitreous enamel coating will provide a ROI ratio of 3.31 when used on brick wall ties. The average life span of a wall tie coated with vitreous enamel is increased by three to five times.

5.2 Recommendations

5.2.1 Applicability

Vitreous enamel coated pintle-and-eye type wall ties can be used to improve performance in both corrosion resistance and wall strength over standard galvanized wall ties of similar design. If this technology is specified for veneer construction, users should visually inspect each wall-tie component to confirm proper coating, especially at bends and at the ends of the pintle. Additionally, proper installation techniques should be used so that the pintle is never bent or sharply impacted.

Before specifying this coating in a brick veneer construction or renovation project, prospective users should survey the state of the market to help ensure that the technology can meet the requirements of the present project. Also, wall ties coated with this material should not be used in applications where there is a need to bend the hardware or the possibility that the tie will be subjected to direct hammering or other sharp impacts.

5.2.2 Implementation

To facilitate awareness of this emerging corrosion-mitigation technology throughout the DoD civil engineering community, a description of it is recommended for incorporation into Unified Facilities Guide Specification UFGS 04 20 00, *Unit Masonry* (November 2015). A new subsection on vitreous-coated rebar can be added to section 2.6.2, "Anchors, Ties, and Bar Positioners," to include language pertaining to the use of, manufacturer quality control, acceptance testing on site, handling, and installation of vitreous enamel coated wall ties.

Vitreous coatings for steel reinforcement materials show promise for reinforced-concrete applications in severely corrosive environments where accelerated corrosion damage can lead to serious equipment damage and/or financial losses. However, broader DoD-wide implementation recommendations should be postponed until coating methods are shown to consistently produce more uniform steel-coverage results and long-term corrosion performance can be rigorously validated in a fully controlled, industry-accepted testing program.

References

ASTM E754-80(2006)e1. 2006. Standard Test Method for Pullout Resistance of Ties and Anchors Embedded in Masonry Mortar Joints. West Conshohocken, PA: ASTM International.

Day, Donna C., Melvin C. Sykes, Charles A. Weiss, Jr., Philip G. Malone, and Earl H. Baugher, Jr. Configuration for Improving Bonding and Corrosion Resistance of Reinforcement Material. U.S. Patent 8,859,105 B2, filed 7 July 2011 and issued 14 October 2014.

Herzberg, Eric F., Norman T. O'Meara, and Rebecca F. Stroh. February 2014. *The Annual Cost of Corrosion for the Facilities and Infrastructure of the Department Of Defense*. Report DAC21T4. Tysons, VA: LMI Government Consulting.

Morefield, S.W., V.F. Hock, C.A. Weiss Jr., P.G. Malone, and M.L. Koenigstein. December 2008. "Reactive Silicate Coatings for Protecting and Bonding Reinforcing Steel in Cement-Based Composites," presented at 26th Army Science Conference, Orlando, FL.

Moser, R., P. Allison, P. Malone, C. Weiss, and S. Morefield. "Physical and Chemical Characterization of the Interface between Concrete and Glass-Ceramic Bonding Enamel MS&T 2010." *Proceedings of the Materials Science & Technology Conference*, October 17–21, 2010, Houston, TX. Red Hook, NJ: Association for Iron and Steel Technology.

Office of Management and Budget (OMB). 1992. *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*. OMB Circular No. A-94. Washington, DC: Office of Management and Budget.

Unified Facilities Guide Specification (UFGS) 04 20 00. November 2015. *Unit Masonry*. Washington DC: Department of Defense.

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Appendix A: ASTM E754 Test Reports

TEC Services
Testing • Engineering • Consulting

March 31, 2011

Mr. Karl Palutke
Mandaree Enterprises
812 Park Drive
Warner Robins, GA 31088

Phone: 478-329-8233
Fax: 478-329-8946
Email: palutke@gmail.com

Subject: **ASTM E754 Masonry Anchor Pull Test Report**
Date Samples Made: 02/09/2011
TEC Services Project No. TEC 11-0867
TEC Lab No. 11-110

Dear Mr. Palutke:

Testing, Engineering and Consulting Services, Inc. (TEC Services), an AASHTO R18 and ISO 17025 certified independent testing laboratory, is pleased to submit this final report of our results for the testing performed on the submitted masonry anchor samples at our Lawrenceville, GA facility in February of 2011. Our services were performed in accordance with the terms and conditions of our Service Agreement dated May 18, 2009. The test results presented only pertain to the samples tested.

It is our understanding that the samples were fabricated on February 9, 2011 by Mandaree Enterprise representatives. Anchor pull testing was performed in accordance with ASTM E754-80 (2006) *Standard Test Method for Pullout Resistance of Ties and Anchors Embedded in Masonry Mortar Joints.* Due to the high strength nature of the test specimens high strength gypsum nor was epoxy resin found suitable to bind the test specimens for tensile testing. Therefore direct connections were made to the prongs of the test specimens using a fabricated testing rig. It should be noted that samples 4-6 were possibly damaged during the initial trials using binders (gypsum and epoxy) versus direct tension pulling.

The specimens were tested until ultimate failure occurred either by achieving the ultimate tensile strength of the anchors or shearing of the mortar joint. Test results are presented in Table 1. Photos of the testing configuration and failure modes are attached to this report.

We appreciate the opportunity to provide our services to you on this project. Please do not hesitate to contact us at your convenience if you have any questions about this report or if we may be of further assistance.

Sincerely,

Testing, Engineering & Consulting Services, Inc.

Trey McCants
Project Manager, Chemist

Shawn P. McCormick
Laboratory Manager

Testing, Engineering & Consulting Services, Inc.
235 Buford Drive | Lawrenceville, GA 30046
770-995-8000 | 770-995-8550 (F) | www.tecservices.com

Table 1 – ASTM E754 Test Results

Sample ID	Peak Load (lbs)	Peak Displacement (in)	Failure Type
Black Coating 1	2,109	0.7320	Mortar Joint Shear
Black Coating 1	2,103	0.7520	Metal Tensile Failure
Black Coating 1	2,310	0.7470	Mortar Joint Shear
Average	**2,174**	**0.7437**	**NA**
Galvanized 1	1,873	0.5210	One sided Metal Tensile Failure
Galvanized 1	1,716	0.5050	One sided Metal Tensile Failure
Galvanized 1	1,659	0.5100	One sided Metal Tensile Failure
Average	**1,749**	**0.5120**	**NA**

Photo 1 – Test Apparatus

Photo 2 – **Mortar Joint Shear**

Photo 3 – **Mortar Bond Failure on One Side**

Photo 4 – Metal Tensile Failure

TEC Services
Testing • Engineering • Consulting

April 25, 2012

Mr. Karl Palutke
Mandaree Enterprises
812 Park Drive
Warner Robins, GA 31088

Phone: 478-329-8233
Fax: 478-329-8946
Email: palutkc@gmail.com

Subject: **ASTM E754 Masonry Anchor Pull Test Report**
TEC Services Project No. TEC 11-0867
TEC Lab No. 12-082

Dear Mr. Palutke:

Testing Engineering and Consulting Services, Inc. (TEC Services) is an AASHTO R18 and International Accreditation Service (IAS) (TL-458) accredited laboratory in compliance with ANS/ISO/IEC Standard 17025:200 and are approved by the Army Corp of Engineers. TEC Services is pleased to submit this final report of our results for the testing performed on the submitted masonry anchor samples at our Lawrenceville, GA facility on February 29, 2012. Our services were performed in accordance with the terms and conditions of our Service Agreement dated May 18, 2009. The test results presented only pertain to the samples tested.

Background Information

Background information was provided by Mandaree Representatives. The ties used in testing were Pintle with 4" projections (RB14). One set of ties was galvanized per ASTM A153 at an application rate of 1.5 oz/ft2. The other set of ties were coated with a layer of vitreous enamel (porcelain), fuse reactive silicate bonded. The original curing time of these samples was 7 days exposed to the Ft. Stewart, Georgia atmosphere with an average high of 70F and an average low of 41F. The samples were 12 months old when pulled from exposure. The mortar used was a traditional masonry mortar. The bricks originated from Cherokee Brick and Tile Company and are designated as product No. 53-20-970, 4" Jumbo Fort Stewart Blend face brick and meet ASTM C216-07 for Grade SW, Type FBS facing brick.

Six test sample configurations, 3 galvanized and 3 vitreous coated, originating from North Carolina and are designated as GNC and VNC, respectively. The six sample configurations originating from Fort Stewart, Georgia and are designated as GST and VST, respectively.

Testing of Samples

Anchor pull testing was performed in accordance with ASTM E754-80 (2006) *Standard Test Method for Pullout Resistance of Ties and Anchors Embedded in Masonry Mortar Joints.* Due to the high strength nature of the test specimens, neither high strength gypsum nor epoxy resin was found suitable to bind the test specimens for tensile testing. Therefore, direct connections were made to the prongs of the test specimens using a fabricated testing rig.

The specimens were tested until failure occurred either by achieving the ultimate tensile strength of the anchors or by shearing of the mortar joint. Test results are reported in Table 1.

Photos of the test samples before and after testing are attached to this report. Load vs. displacement curves for each specimen are also attached to this report. It was observed that the thickness of the mortar joints and the depth of the tie placement varied among the samples.

Table 1 – ASTM E754 Test Results

Sample ID	Peak Load (lbs)	Displacement at Peak Load (in)	Failure Type
VST 1	1,911	0.1940	One sided Metal Tensile Failure
VST 2*	1,146	0.1825	Mortar Joint Shear
VST 3	2,221	0.5015	One sided Metal Tensile Failure
Average	**1,760**	**0.2927**	**NA**
GST 1	1,959	0.1038	One sided Metal Tensile Failure
GST 2	1,436	0.1995	Double sided Metal Tensile Failure
GST 3	1,487	0.0818	Mortar Joint Shear
Average	**1,627**	**0.1284**	**NA**
VNC 1	2,258	0.6208	One sided Metal Tensile Failure
VNC 2	2,235	0.3443	One sided Metal Tensile Failure
VNC 3	2,261	0.3398	One sided Metal Tensile Failure
Average	**2,251**	**0.4350**	
GNC 1	2,962	0.1960	One sided Metal Tensile Failure
GNC 2	1,479	0.1338	Mortar Joint Shear
GNC 3	1,261	0.1478	One sided Metal Tensile Failure
Average	**1,901**	**0.1592**	**NA**

*Sample may have been damaged in shipping

TESTING, ENGINEERING & CONSULTING SERVICES, INC.

Trey McCants
Project Manager, Chemist

Shawn P. McCormick
Laboratory Manager

Attachments: Load vs. Displacement Graphs (4)
Photos of samples after failure (13)

Report of Testing for Masonry Brick Anchors
TEC Services Project No. 11-0867
TEC Lab No. 12-082
April 25, 2012

Figure 1 – VST Samples

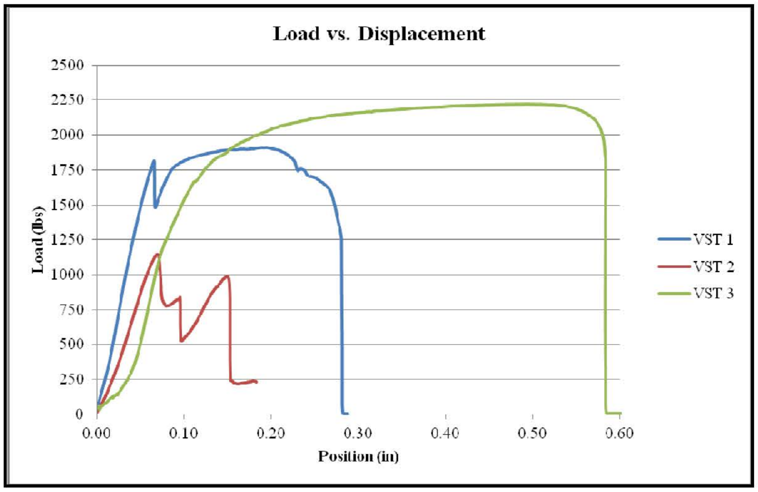


Figure 2 – GST Samples

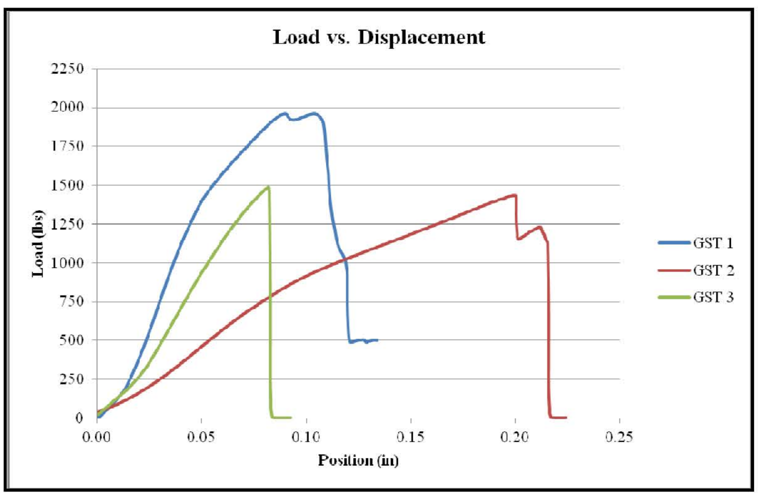


Figure 3 – VNC Samples

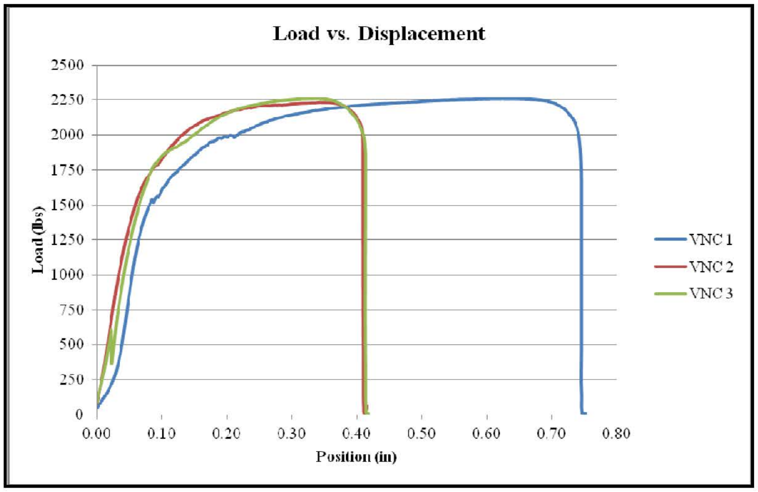


Figure 4 – GNC Samples

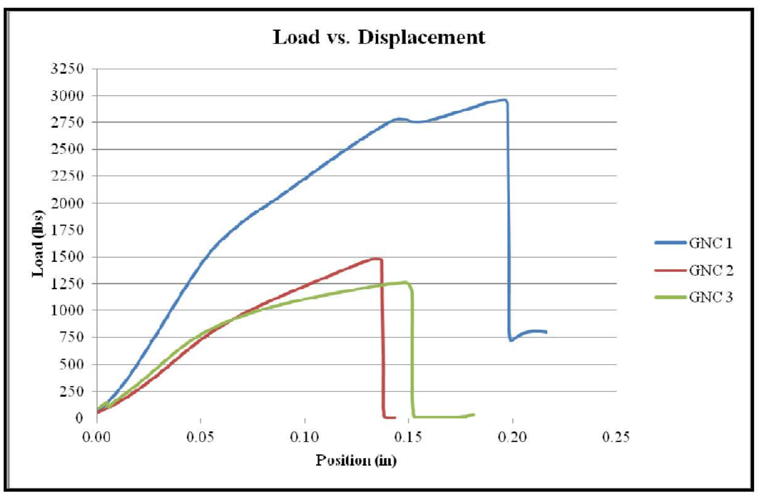


Photo 1 – Test Apparatus

Photo 2 – Mode of Failure – VST #1

Photo 3 – Mode of Failure – VST #2

Photo 4 – Mode of Failure – VST #3

Photo 5 – Mode of Failure – GST #1

Report of Testing for Masonry Brick Anchors *April 25, 2012*
TEC Services Project No. 11-0867
TEC Lab No. 12-082

Photo 6 – Mode of Failure – GST #2

Photo 7 – Mode of Failure – GST #3

Page **8** of **11**

Report of Testing for Masonry Brick Anchors
TEC Services Project No. 11-0867
TEC Lab No. 12-082

April 25, 2012

Photo 8 – Mode of Failure – VNC #1

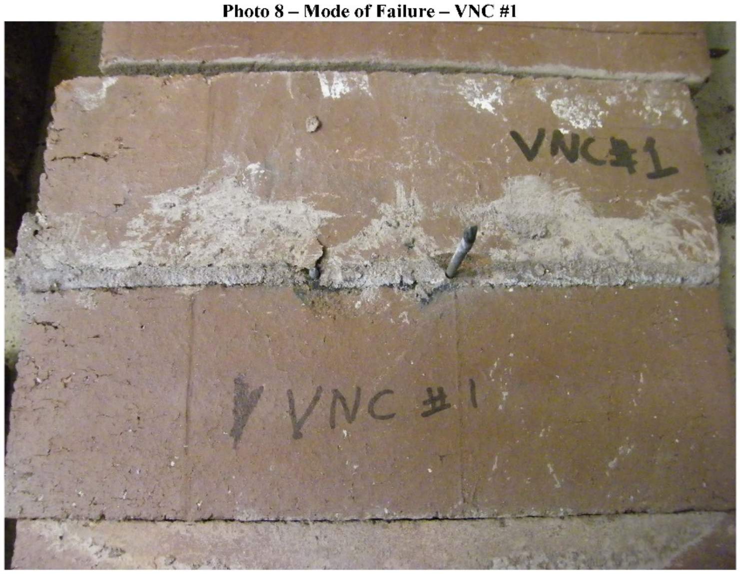


Photo 9 – Mode of Failure – VNC #2

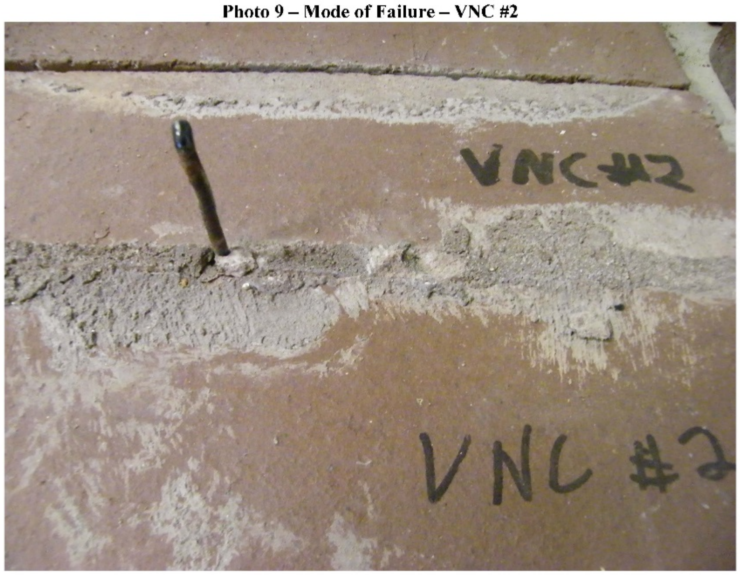


Photo 10 – Mode of Failure – VNC #3

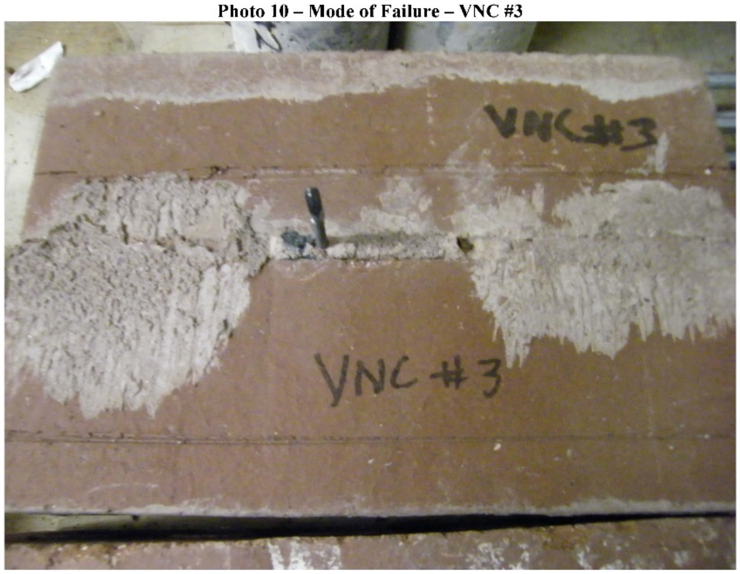
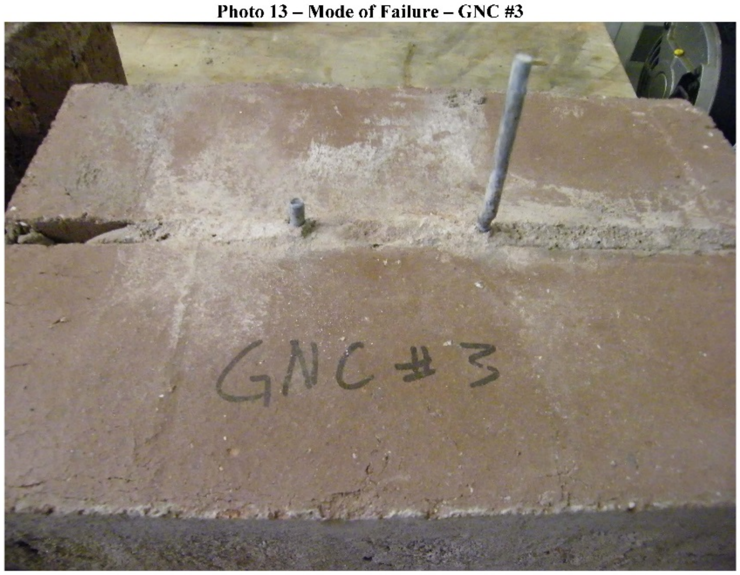


Photo 11 – Mode of Failure – GNC #1

Report of Testing for Masonry Brick Anchors April 25, 2012
TEC Services Project No. 11-0867
TEC Lab No. 12-082

Photo 12 – Mode of Failure – GNC #2

Photo 13 – Mode of Failure – GNC #3



Page **11** of **11**

August 28, 2012

Mr. Karl Palutke
Mandaree Enterprises
812 Park Drive
Warner Robins, GA 31088

Phone: 478-329-8233
Fax: 478-329-8946
Email: palutke@gmail.com

Subject: **ASTM E754 Masonry Anchor Pull Test Report**
TEC Services Project No. TEC 11-0867
TEC Lab No. 12-380

Dear Mr. Palutke:

Testing, Engineering and Consulting Services, Inc. (TEC Services), an AASHTO R18 and ISO 17025 certified independent testing laboratory, is pleased to submit this final report of our results for the testing performed on the submitted masonry anchor samples at our Lawrenceville, GA facility on August 9, 2012. Our services were performed in accordance with the terms and conditions of our Service Agreement dated May 18, 2009. The test results presented only pertain to the samples tested.

Background Information – Provided by Mandaree Representatives

The ties used in testing were Pintle with 4" projections (RB14). One set of ties were galvanized per ASTM A153 at an application of 1.5 oz/ft2. The other set of ties were coated with a layer of vitreous enamel (porcelain), fuse reactive silicate bonded. The original curing time of these samples was 7 days exposed to the Ft. Stewart, Georgia atmosphere with an average high of 70F and an average low of 41F. The samples were at 12 months of age when pulled from exposure. The mortar used was a traditional masonry mortar. The bricks originated from Cherokee Brick and Tile Company and are designated as product No. 53-20-970, 4" Jumbo Fort Stewart Blend face brick and meet ASTM C216-07 for Grade SW, Type FBS facing brick.

Six test sample configurations, 3 galvanized and 3 vitreous coated, originated from North Carolina and are designated as either GNC or VNC, respectively. The remaining six sample configurations originated from Fort Stewart, Georgia and are designated as GST or VST, respectively.

Testing of Samples

Anchor pull testing was performed in accordance with ASTM E754-80 (2006) *Standard Test Method for Pullout Resistance of Ties and Anchors Embedded in Masonry Mortar Joints.* Due to the high strength nature of the test specimens high strength gypsum nor epoxy resin was found suitable to bind the test specimens for tensile testing. Therefore direct connections were made to the prongs of the test specimens using a fabricated testing rig.

The specimens were tested until ultimate failure occurred either by achieving the ultimate tensile strength of the anchors or shearing of the mortar joint. Test results are presented in Table 1.

Photos of the test samples before and after testing are attached to this report. Load vs. displacement curves for each specimen are also attached to this report. It was observed that the thickness of the mortar joints and the depth of the tie placement varied amongst the samples.

Table 1 – ASTM E754 Test Results

Sample ID	Peak Load (lbs)	Displacement at Peak Load (in)	Failure Type
VST 4	2,132	0.4715	One sided Metal Tensile Failure
VST 5	2,252	0.6225	One sided Metal Tensile Failure
VST 6	2,235	0.7573	One sided Metal Tensile Failure
Average	**2,206**	**0.6171**	**NA**
GST 4	1,575	0.2970	One sided Metal Tensile Failure
GST 5	1,658	0.0930	Double sided Metal Tensile Failure
GST 6	2,487	0.3103	Double sided Metal Tensile Failure
Average	**1,907**	**0.2334**	**NA**
VNC 4	2,238	0.4333	One sided Metal Tensile Failure
VNC 5	2,203	0.7560	One sided Metal Tensile Failure
VNC 6	2,240	0.6395	One sided Metal Tensile Failure
Average	**2,227**	**0.6096**	
GNC 4	1,391	0.3703	One sided Metal Tensile Failure
GNC 5	1,752	0.2593	One sided Metal Tensile Failure
GNC 6	1,782	0.2468	One sided Metal Tensile Failure
Average	**1,642**	**0.2921**	**NA**

We appreciate the opportunity to provide our services to you on this project. Please do not hesitate to contact us at your convenience if you have any questions about this report or if we may be of further assistance.

Sincerely,

Testing, Engineering & Consulting Services, Inc.

Trey McCants
Project Manager, Chemist

Shawn P. McCormick
Laboratory Manager

Attachments: Load vs. Displacement Graphs (12)
Photos of samples after failure (12)

Photos of Failure Modes


VST6


GST4

Report of Testing for Masonry Brick Anchors
TEC Services Project No. 11-0867
TEC Lab No. 12-380

August 28, 2012

Report of Testing for Masonry Brick Anchors *August 28, 2012*
TEC Services Project No. 11-0867
TEC Lab No. 12-380


UNC6


GNC4


GNC5


GNC6

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Testing, Engineering & Consulting Services, Inc.
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TEC Services
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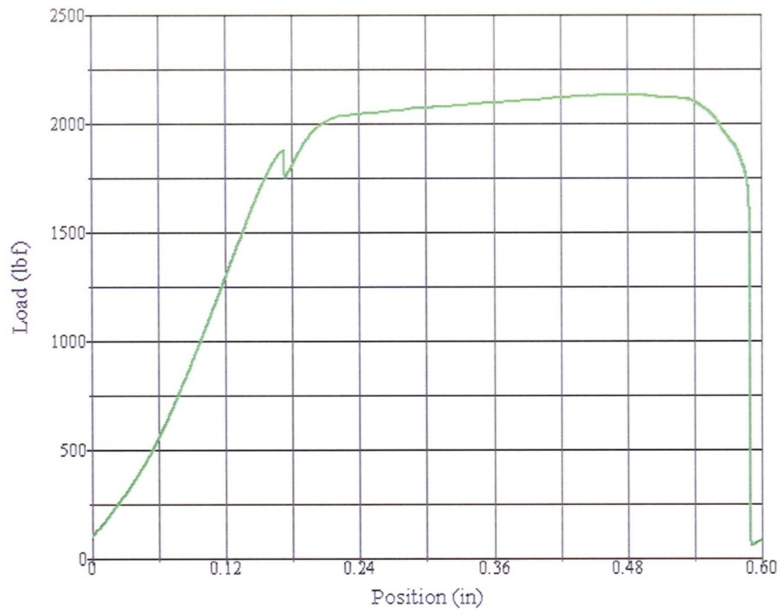

Test Summary

Counter:	9481
Elapsed Time:	00:06:00
Procedure Name:	ASTM E754 - Masonry Anchor Pull Out
Start Date:	8/8/2012
Start Time:	5:09:01 PM
End Date:	8/8/2012
End Time:	5:15:01 PM
Workstation:	INSTRON2
Tested By:	McCants
Specimen Identification:	VST 4
Date Made:	

Test Results

Peak Load:	2131.2 lbf
Peak Position:	0.5988 in
Position at Peak Load:	0.4715 in

INSTRON29478 5:50:51 PM 8/22/2012

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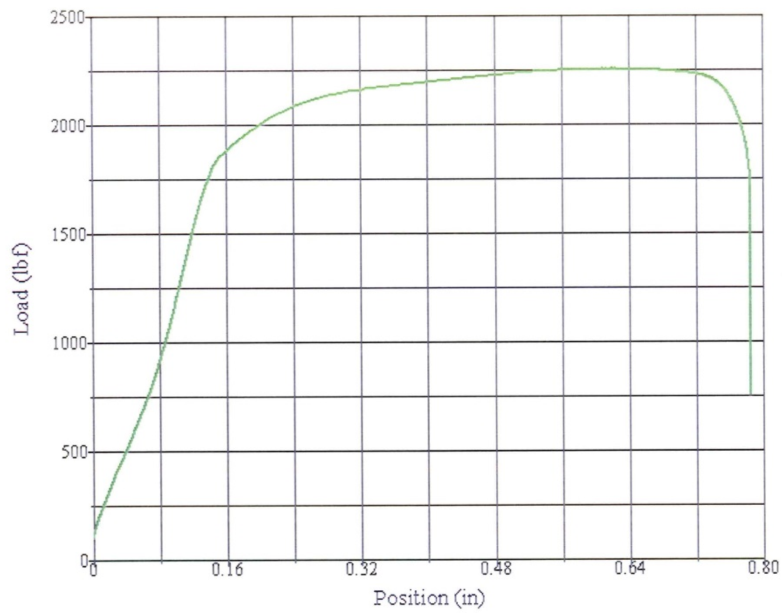

Test Summary

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Procedure Name:	ASTM A370 - Conac Anchors - Load Testing
Start Date:	8/8/2012
Start Time:	4:03:39 PM
End Date:	8/8/2012
End Time:	4:06:16 PM
Workstation:	INSTRON2
Tested By:	McCants
Specimen Identification:	VST 5
Operator:	PJJ

Test Results

Peak Load:	2252 lbf
Position at Peak Load:	0.6225 in
Position at Peak Load#2:	0.6225 in

INSTRON29479 5:51:25 PM 8/22/2012

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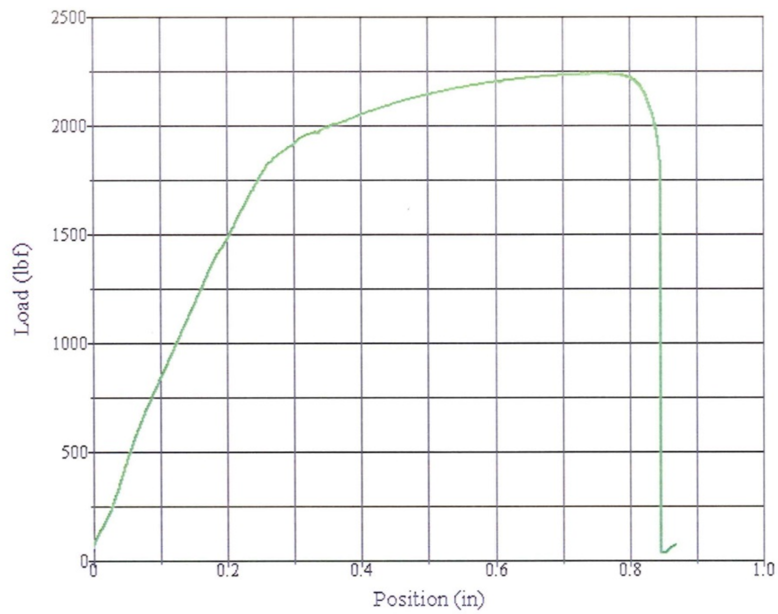

Test Summary		Test Results	
Counter:	9479	Peak Load:	2235.4 lbf
Elapsed Time:	00:08:40	Peak Position:	0.8670 in
Procedure Name:	ASTM E754 - Masonry Anchor Pull Out	Position at Peak Load:	0.7573 in
Start Date:	8/8/2012		
Start Time:	4:28:58 PM		
End Date:	8/8/2012		
End Time:	4:37:38 PM		
Workstation:	INSTRON2		
Tested By:	McCants		
Specimen Identification:	VST 6		
Date Made:			

INSTRON29497 5:53:20 PM 8/22/2012

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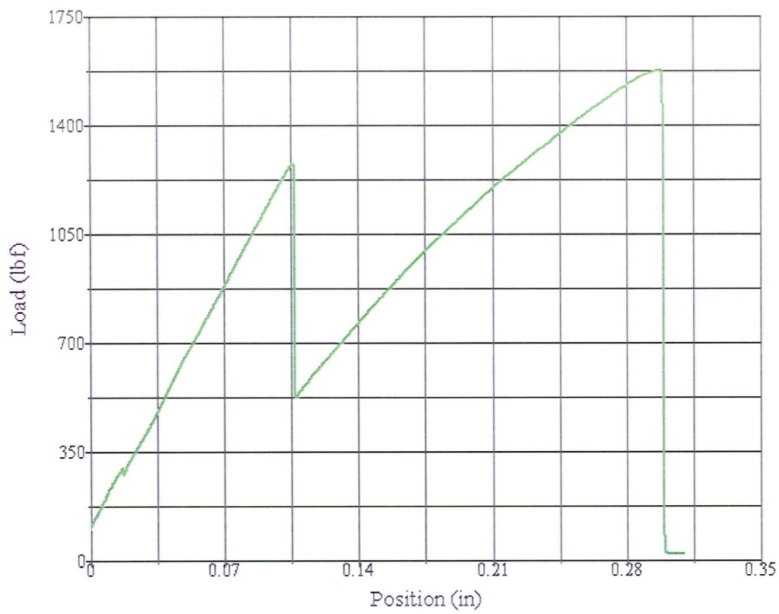

Test Summary

Counter:	9497
Elapsed Time:	00:03:05
Procedure Name:	ASTM E754 - Masonry Anchor Pull Out
Start Date:	8/9/2012
Start Time:	6:05:39 PM
End Date:	8/9/2012
End Time:	6:08:44 PM
Workstation:	INSTRON2
Tested By:	McCants
Specimen Identification:	GST 4
Date Made:	

Test Results

Peak Load:	1575.0 lbf
Peak Position:	0.3095 in
Position at Peak Load:	0.2970 in

INSTRON29496 5:53:15 PM 8/22/2012

Testing, Engineering & Consulting Services, Inc.
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TEC Services
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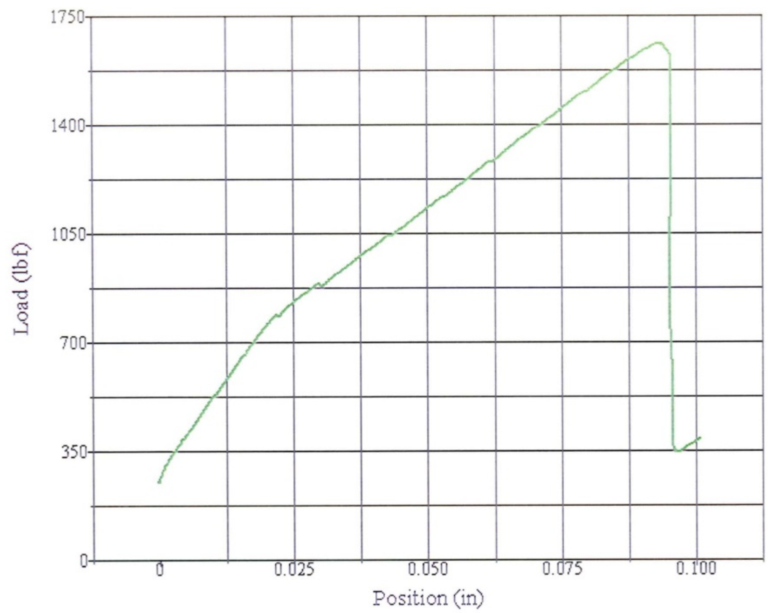

Test Summary

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Start Time:	5:59:34 PM
End Date:	8/9/2012
End Time:	6:00:35 PM
Workstation:	INSTRON2
Tested By:	McCants
Specimen Identification:	GST 5
Date Made:	

Test Results

Peak Load:	1658.1 lbf
Peak Position:	0.1008 in
Position at Peak Load:	0.0930 in

INSTRON29498 5:53:25 PM 8/22/2012

Testing, Engineering & Consulting Services, Inc.
235 Buford Drive
Lawrenceville, GA 30046
770-995-8000 | Office
770-995-8550 | Fax

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Test Summary

Counter:	9498
Elapsed Time:	00:03:39
Procedure Name:	ASTM E754 - Masonry Anchor Pull Out
Start Date:	8/10/2012
Start Time:	10:42:55 AM
End Date:	8/10/2012
End Time:	10:46:34 AM
Workstation:	INSTRON2
Tested By:	McCants
Specimen Identification:	GST 6
Date Made:	

Test Results

Peak Load:	2486.7 lbf
Peak Position:	0.3595 in
Position at Peak Load:	0.3103 in

INSTRON29488 5:52:16 PM 8/22/2012

Testing, Engineering & Consulting Services, Inc.
235 Buford Drive
Lawrenceville, GA 30046
770-995-8000 | Office
770-995-8550 | Fax

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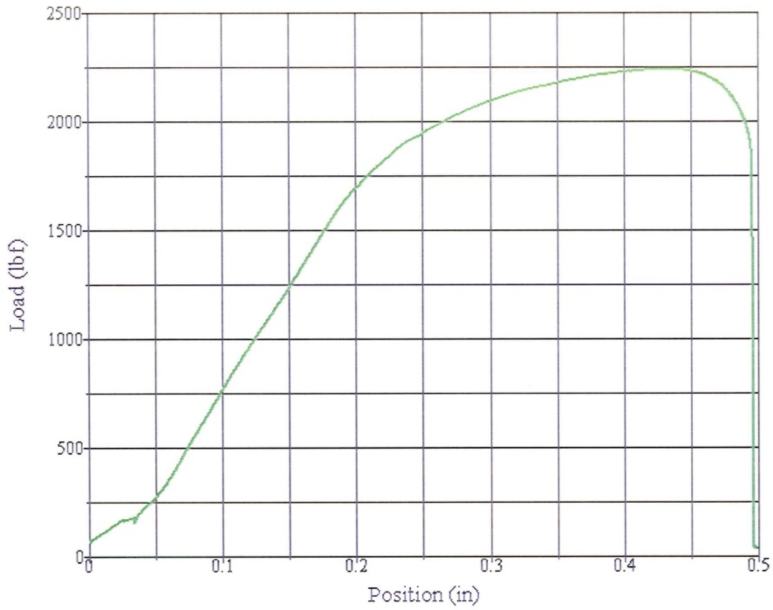

Test Summary	
Counter:	9488
Elapsed Time:	00:06:45
Procedure Name:	ASTM E754 - Masonry Anchor Pull Out
Start Date:	8/9/2012
Start Time:	11:17:25 AM
End Date:	8/9/2012
End Time:	11:24:10 AM
Workstation:	INSTRON2
Tested By:	McCants
Specimen Identification:	VNC 4
Date Made:	

Test Results	
Peak Load:	2238.5 lbf
Peak Position:	0.6733 in
Position at Peak Load:	0.4333 in

INSTRON29490 5:52:27 PM 8/22/2012

Testing, Engineering & Consulting Services, Inc.
235 Buford Drive
Lawrenceville, GA 30046
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770-995-8550 | Fax

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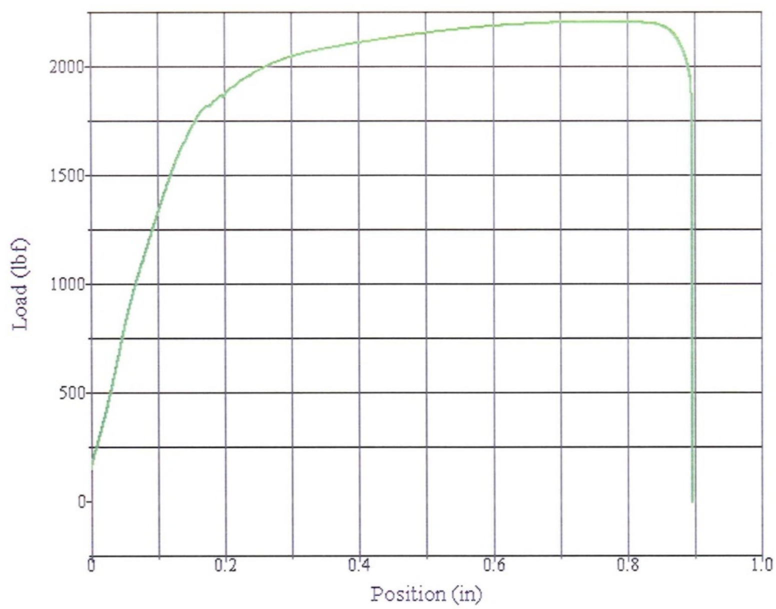

Test Summary		Test Results	
Counter:	9490	Peak Load:	2203.0 lbf
Elapsed Time:	00:08:59	Peak Position:	0.8970 in
Procedure Name:	ASTM E754 - Masonry Anchor Pull Out	Position at Peak Load:	0.7560 in
Start Date:	8/9/2012		
Start Time:	1:28:30 PM		
End Date:	8/9/2012		
End Time:	1:37:29 PM		
Workstation:	INSTRON2		
Tested By:	McCants		
Specimen Identification:	VNC 5		
Date Made:			

INSTRON29489 5:52:22 PM 8/22/2012

Testing, Engineering & Consulting Services, Inc.
235 Buford Drive
Lawrenceville, GA 30046
770-995-8000 | Office
770-995-8550 | Fax

TEC Services
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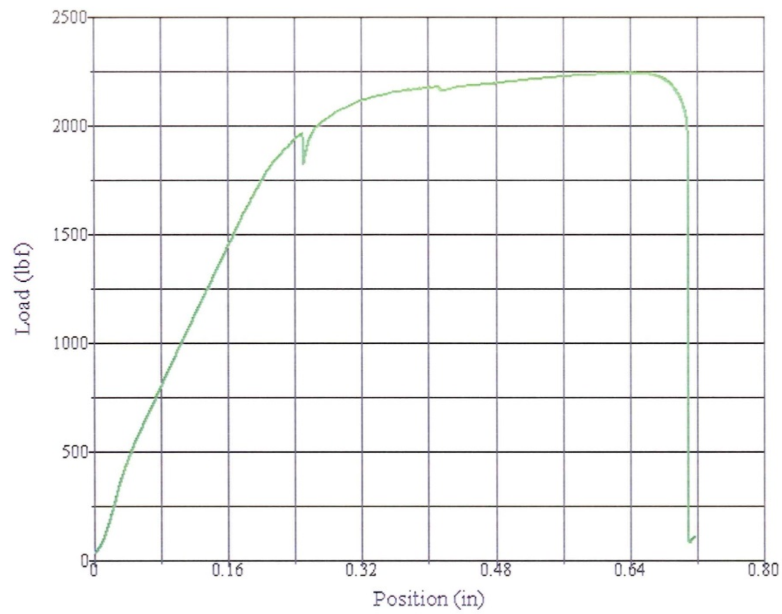

Test Summary

Counter:	9489
Elapsed Time:	00:07:11
Procedure Name:	ASTM E754 - Masonry Anchor Pull Out
Start Date:	8/9/2012
Start Time:	11:45:11 AM
End Date:	8/9/2012
End Time:	11:52:22 AM
Workstation:	INSTRON2
Tested By:	McCants
Specimen Identification:	VNC 6
Date Made:	

Test Results

Peak Load:	2239.9 lbf
Peak Position:	0.7175 in
Position at Peak Load:	0.6395 in

INSTRON29493 5:52:49 PM 8/22/2012

Testing, Engineering & Consulting Services, Inc.
235 Buford Drive
Lawrenceville, GA 30046
770-995-8000 | Office
770-995-8550 | Fax

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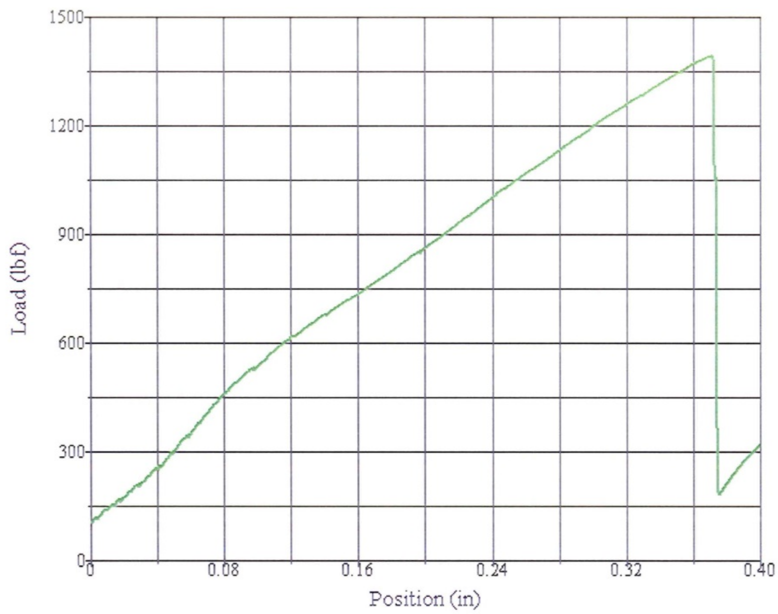


Test Summary

Counter:	9493
Elapsed Time:	00:04:48
Procedure Name:	ASTM E754 - Masonry Anchor Pull Out
Start Date:	8/9/2012
Start Time:	5:18:00 PM
End Date:	8/9/2012
End Time:	5:22:48 PM
Workstation:	INSTRON2
Tested By:	McCants
Specimen Identification:	GNC 4
Date Made:	

Test Results

Peak Load:	1391.1 lbf
Peak Position:	0.4578 in
Position at Peak Load:	0.3703 in

CHEROKEE BRICK & TILE COMPANY

KENNETH D. SAMS
CHAIRMAN & CEO

MICHAEL E. PEAVY
PRESIDENT

DONALD L. CROWELL
EXEC. VICE PRESIDENT/GEN MGR.

WATERVILLE ROAD
P.O. BOX 4567
MACON, GEORGIA 31208

TELEPHONE 478-781-6800
FAX 478-781-8964

June 20, 2011

Mandaree Enterprises
812 Park Drive
Warner Robins, GA 31088

Job: Fort Stewart

To whom it may concern,

This is to certify that Cherokee Brick & Tile Company product No. 53-20-970, 4" Jumbo Fort Stewart Blend face brick are manufactured so as to meet ASTM Designation C-216-07 for Grade SW, Type FBS facing brick.

Attached is a test report as performed by an independent testing laboratory on this particular brick.

CHEROKEE BRICK AND TILE COMPANY, INC.

Clare Cauley

Clare Cauley
Sales Office Manager

Laurie J. Hardy
Notary Public

3-9-13
My Commission Expires

NOTARY PUBLIC
SEAL
BIBB CO., GA
LAURIE J. HARDY
Notary Public
STATE OF GEORGIA
My Comm. Exp. 3/09/2013

6/20/11
Date

C.C.:kb
Enclosure

Cherokee Brick & Tile Company # 197 **Material Safety Data Sheet**

Cherokee Brick & Tile Company
3250 Waterville Road
Macon GA 31206

For additional information contact:
James V. Owens,
General Manager of Operations
(478)781-6800

Date Completed: July 1994
Latest Revision: May 30, 2006

SECTION I – PRODUCT IDENTIFICATION

Product Name: Brick

Chemical Family: Predominately Aluminum Silicates
Formula: Mixture

SECTION II – HAZARDOUS INGREDIENTS

Ingredients	CAS #	% Weight	Exposure Limits: OSHA PEL mg/m^3	Exposure Limits: ACGIH TLV mg/m^3
Aluminum Silicates	Various	50 – 85	15	10
Quartz	14808-60-7	Varies	10 / %SiO_2 + 2 (respirable)	0.025 (respirable)
Chromium compounds	Various	0 – 3	Not available	Not available
Manganese compounds	Various	0 – 3	Not available	Not available
Iron Compounds as granular body additives	Various	0 – 3	Not available	Not available
Calcium compounds	Various	0 – 3	Not available	Not available

The above chemistries are provided for industrial hygiene and environmental purposes and are not intended to represent product specifications. This information has been compiled from data believed to be reliable. Elements such as aluminum, arsenic, boron, calcium, chromium, cobalt, copper, lead, molybdenum, nickel, tin, titanium, vanadium, and zirconium may be present in trace amounts. Brick products as shipped do not present an exposure hazard.

SECTION III – PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point: NA
Vapor Pressure: NA
Melting Point: NA
Vapor Density: NA
Specific Gravity: 2.6
Solubility in Water: Negligible
Appearance and Odor: Granular solid, essentially odorless. Bricks come in a wide range of colors.

SECTION IV – FIRE AND EXPLOSION HAZARD DATA	**SECTION V – REACTIVITY**
Bricks as shipped do not pose a fire or explosion hazard.	Bricks as shipped are not reactive

SECTION VI – HEALTH HAZARD DATA

Bricks as shipped do not present an inhalation, ingestion or contact hazard. However, operations such as sawing and grinding may result in the following effects.

ACUTE EFFECTS OF OVEREXPOSURE:

Eye: May cause irritation by abrasion with dust or chips.

Skin: Brick dust or chips may cause allergic reactions in hypersensitive individuals; May cause cuts and skin abrasions.

Inhalation: Brick dust or chips may cause congestion and irritation in nasal and respiratory passages.

Ingestion: No known acute effects.

CHRONIC EFFECTS OF OVEREXPOSURE:
Excessive exposures to respirable particulates (dust) over an extended period of time may result in the development of pulmonary diseases such as silicosis.

SECTION VI – HEALTH HAZARD DATA (continued)

CARCINOGENICITY:

The following carcinogenicity classifications for crystalline silica have been established by the following agencies:

OSHA: Not regulated as a carcinogen
IARC: Group 1 carcinogenic in humans
NIOSH: Carcinogen, with no further categorization
NTP: Known carcinogen

WARNING: Brick dust may contain crystalline silica, a chemical that has been determined by the agencies listed above to cause cancer. Inhalation of brick dust above established or recommended exposure levels should be avoided by use of wet sawing or shaping and/or use of a NIOSH and/or MSHA approved respirator. Always stack and store bricks in a stable manner to avoid falling hazards.

SECTION VII – PRECAUTIONS FOR SAFE HANDLING AND USE

Ventilation:	Provide adequate ventilation to maintain exposures below the OSHA PEL and ACGIH TLV for quartz and other substances.
Respiratory Protection:	For airborne concentration exceeding the OSHA PEL or ACGIH TLV use a NIOSH and/or MSHA approved respirator.
Other Protective Equipment:	Eye and Face: Face shields should be used when sawing brick. Skin: Use gloves and or protective clothing if abrasions or allergic reactions are experienced. Other: Use of steel toe shoes is recommended when handling brick.
Other controls:	Use of wet sawing methods is recommended anytime that bricks must be cut.

SECTION VIII – FIRST AID AND MEDICAL

Inhalation:	Remove from exposure to airborne particulates. Consult a physician if breathing does not return to normal.
Skin:	Wash with soap and water. If an allergic reaction causes a rash that does not heal with in a few days consult a physician. Treat abrasions as any other scrape or cut with disinfectants and bandages.
Eye:	Flush with running water. Obtain medical assistance if irritation continues
Medical Conditions Aggravated by Exposure:	Excessive dust exposure may aggravate any existing respiratory disorders or diseases. Possible complications or allergies resulting in irritation to skin, eyes, and respiratory tract may occur from excessive exposure to dusts.

SECTION IX – OTHER REGULATIONS

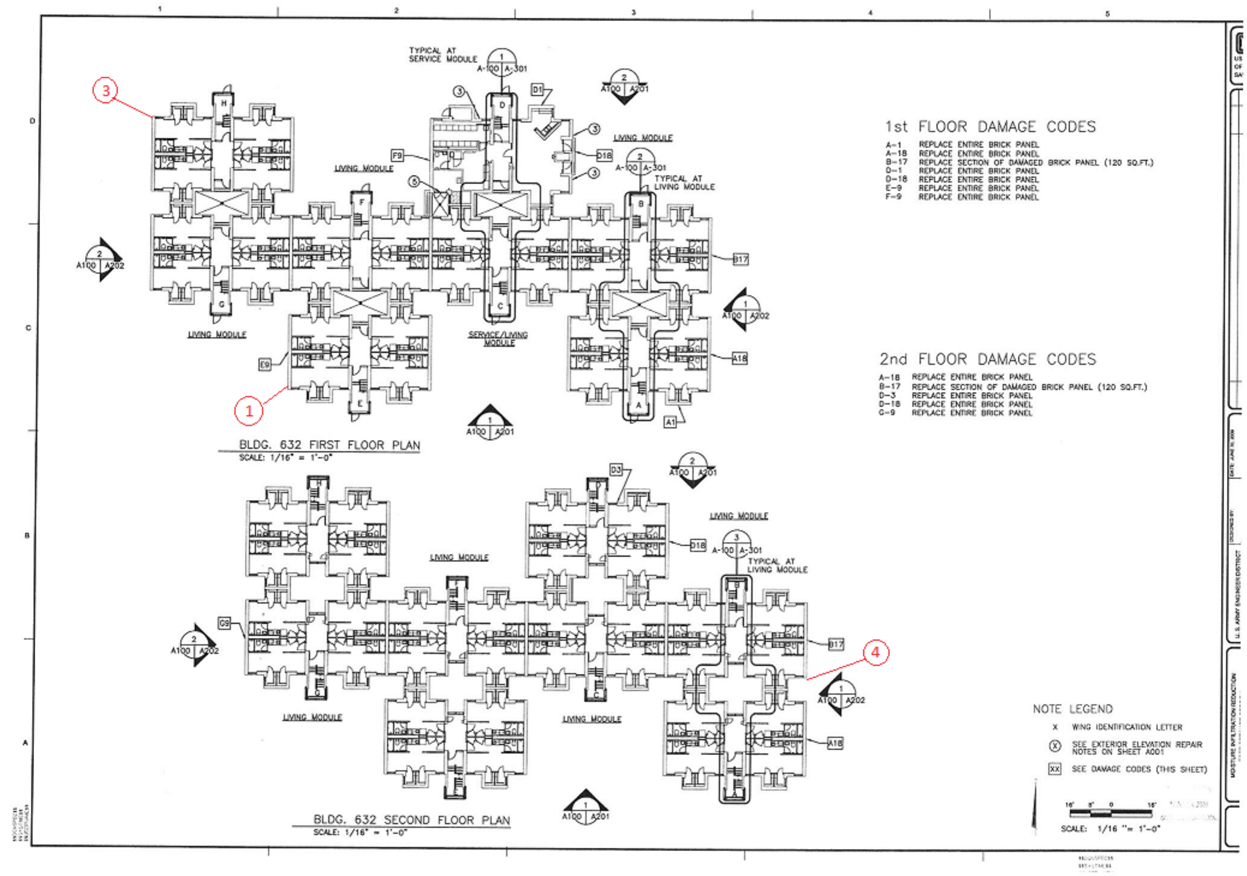
RCRA:	Brick in its solid form is typically considered a non-hazardous waste for disposal, but local regulation may vary, therefore all waste must be disposed/recycled/reclaimed in accordance with federal, state, and local environmental control regulations. Water containing brick solids, such as from wet sawing operations, should also be disposed of in accordance with federal, state and local environmental regulation. Brick waste should not be used as a blasting agent.
EPCRA Section 311/312:	Bricks as shipped are not a Section 311/312 reportable product.
EPCRA Section 313:	Bricks as shipped are not subject to the Section 313, Toxic Chemical Release Inventory reporting requirements.
DOT:	Bricks as shipped are not hazardous materials per DOT regulations.

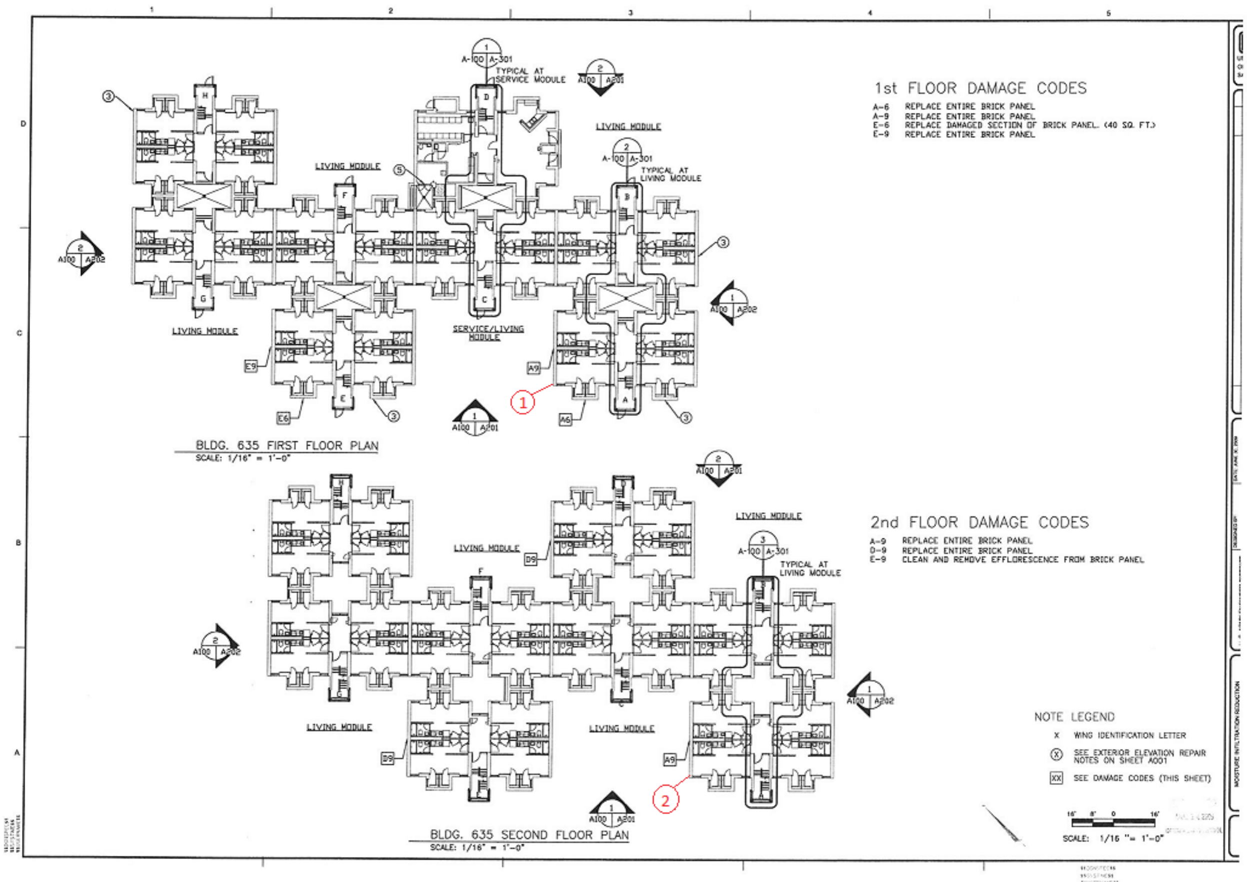
SECTION X – OTHER INFORMATION

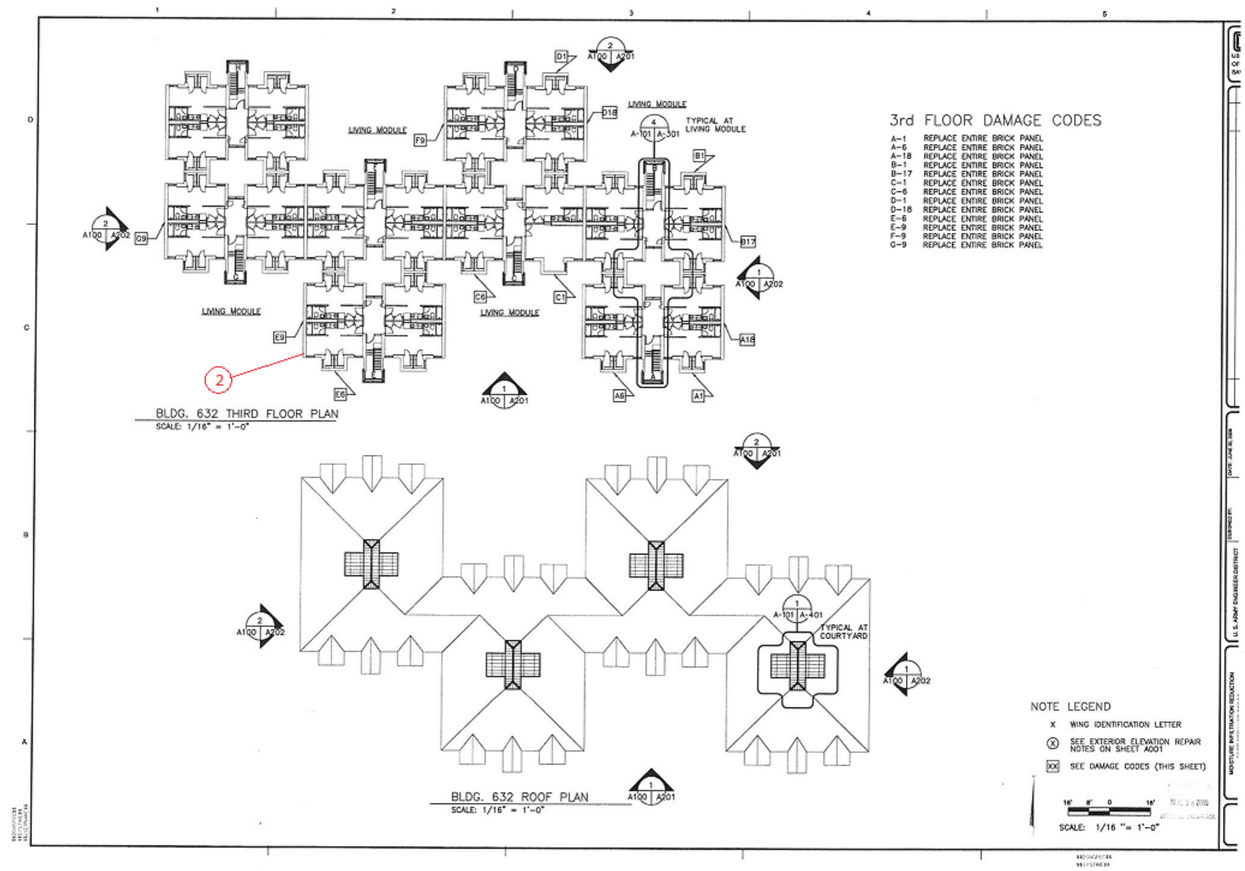
Cherokee Brick & Tile Company considers our product an "article" as defined in 30 CFR 1200(b)(g)(iv) and 40 CFR 372.38. As an article, an MSDS is not required and the product is exempt from all other requirements of the hazard communication standard. OSHA requires an MSDS for brick because it is occasionally dry sawed. We recommend only wet sawing of brick.

This MSDS was prepared with information believed accurate at the time of preparation and was prepared and provided in good faith. However, Cherokee Brick & Tile Company assumes no responsibility as to the accuracy or suitability of such information and no warranty expressed or implied is made.

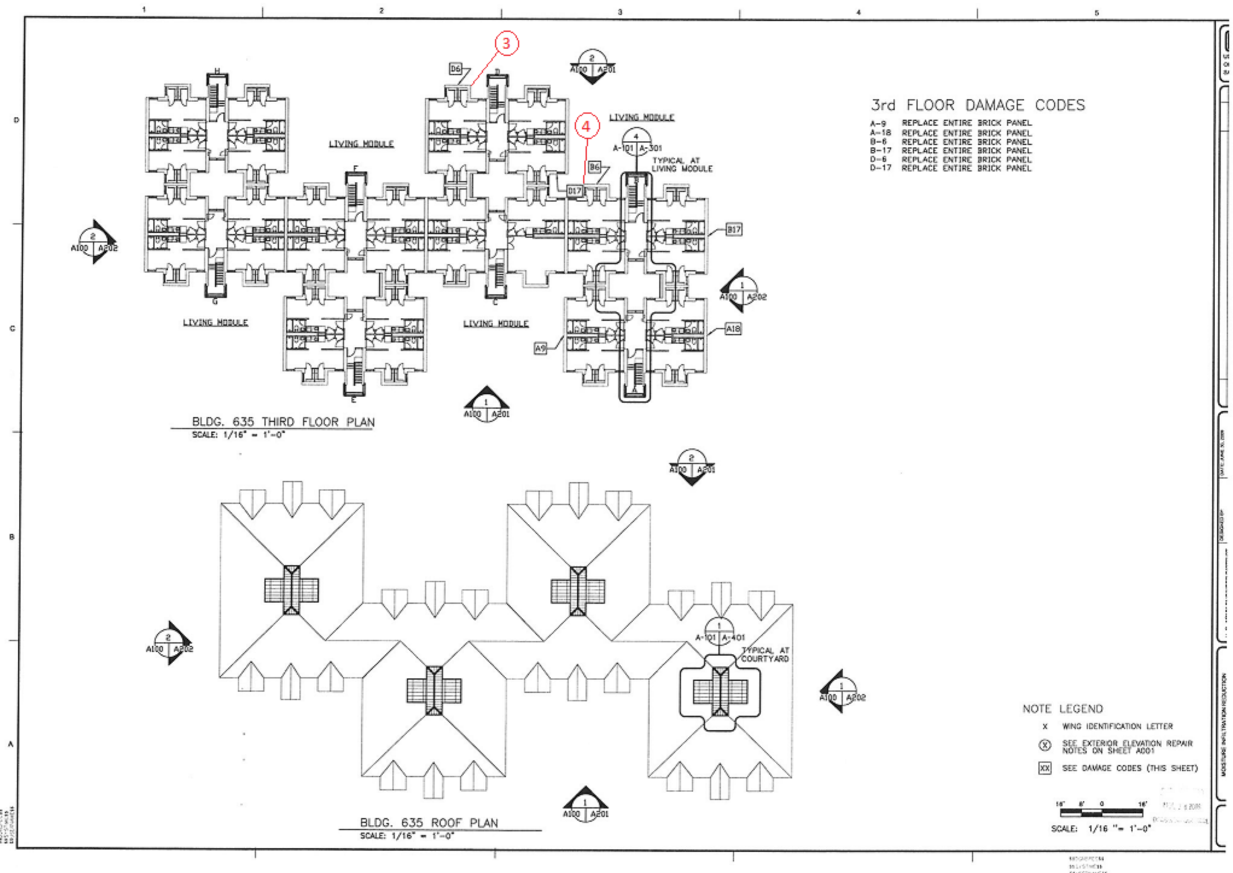
Appendix B: Borescope Inspection Locations




1st FLOOR DAMAGE CODES
A-6 REPLACE ENTIRE BRICK PANEL
A-9 REPLACE ENTIRE BRICK PANEL
E-6 REPLACE DAMAGED SECTION OF BRICK PANEL. (40 SQ. FT.)
E-9 REPLACE ENTIRE BRICK PANEL
TYPICAL AT SERVICE MODULE
TYPICAL AT LIVING MODULE
LIVING MODULE
SERVICE/LIVING MODULE
BLDG. 635 FIRST FLOOR PLAN
SCALE: 1/16" = 1'-0"
2nd FLOOR DAMAGE CODES
A-9 REPLACE ENTIRE BRICK PANEL
D-9 REPLACE ENTIRE BRICK PANEL
E-9 CLEAN AND REMOVE EFFLORESCENCE FROM BRICK PANEL
NOTE LEGEND
X WING IDENTIFICATION LETTER
SEE EXTERIOR ELEVATION REPAIR NOTES ON SHEET A001
SEE DAMAGE CODES (THIS SHEET)
BLDG. 635 SECOND FLOOR PLAN
SCALE: 1/16" = 1'-0"
SCALE: 1/16 "= 1'-0"



3rd FLOOR DAMAGE CODES
A-1 REPLACE ENTIRE BRICK PANEL
A-6 REPLACE ENTIRE BRICK PANEL
A-18 REPLACE ENTIRE BRICK PANEL
B-1 REPLACE ENTIRE BRICK PANEL
B-17 REPLACE ENTIRE BRICK PANEL
C-1 REPLACE ENTIRE BRICK PANEL
C-6 REPLACE ENTIRE BRICK PANEL
D-1 REPLACE ENTIRE BRICK PANEL
D-18 REPLACE ENTIRE BRICK PANEL
E-6 REPLACE ENTIRE BRICK PANEL
E-9 REPLACE ENTIRE BRICK PANEL
F-9 REPLACE ENTIRE BRICK PANEL
G-9 REPLACE ENTIRE BRICK PANEL
LIVING MODULE
TYPICAL AT LIVING MODULE
BLDG. 632 THIRD FLOOR PLAN
SCALE: 1/16" = 1'-0"
TYPICAL AT COURTYARD
BLDG. 632 ROOF PLAN
SCALE: 1/16" = 1'-0"
NOTE LEGEND
X WING IDENTIFICATION LETTER
SEE EXTERIOR ELEVATION REPAIR NOTES ON SHEET A001
SEE DAMAGE CODES (THIS SHEET)
SCALE: 1/16 "= 1'-0"


3rd FLOOR DAMAGE CODES
A-9 REPLACE ENTIRE BRICK PANEL
A-18 REPLACE ENTIRE BRICK PANEL
B-6 REPLACE ENTIRE BRICK PANEL
B-17 REPLACE ENTIRE BRICK PANEL
D-6 REPLACE ENTIRE BRICK PANEL
D-17 REPLACE ENTIRE BRICK PANEL
LIVING MODULE
LIVING MODULE
LIVING MODULE
LIVING MODULE
TYPICAL AT LIVING MODULE
A-101 A-301
D6
D17
B6
B17
A9
A18
3
4
BLDG. 635 THIRD FLOOR PLAN
SCALE: 1/16" = 1'-0"
A100 A201
A100 A202
TYPICAL AT COURTYARD
A-101 A-401
BLDG. 635 ROOF PLAN
SCALE: 1/16" = 1'-0"
NOTE LEGEND
X WING IDENTIFICATION LETTER
SEE EXTERIOR ELEVATION REPAIR NOTES ON SHEET A001
XX SEE DAMAGE CODES (THIS SHEET)
SCALE: 1/16 "= 1'-0"

Appendix C: Visual Inspection Reports

6 month destructive coupon inspection

		Ft. Stewart, GA			Duck, NC		
		Standard Steel	Galvanized Steel	Viterous Cotated Steel	Standard Steel	Galvanized Steel	Viterous Cotated Steel
Coupon # 1	Inside the Mortar [%]	20%	10%	0%	10%	10%	0%
	Outside the Mortar [%]	100%	100%	0%	100%	100%	0%
	Corrosion Ingress [mm]	4.5	2	0	1.5	0.25	0
Coupon # 2	Inside the Mortar [%]	10%	10%	0%	10%	10%	0%
	Outside the Mortar [%]	100%	100%	0%	100%	100%	0%
	Corrosion Ingress [mm]	1.5	0.5	0	1.5	0.5	0

		Building 632		Building 635	
		Pintle	Wall Tie	Pintle	Wall Tie
Boroscope Site	1.1	0%	0%	0%	0%
	1.2	0%	0%	0%	0%
	1.3	0%	5%	0%	0%
	2.1	0%	0%	5%	5%
	2.2	0%	5%	0%	0%
	2.3	0%	0%	0%	0%
	3.1	0%	0%	0%	0%
	3.2	0%	0%	5%	5%
	3.3	***	0%	0%	0%
	4.1	0%	0%	0%	0%
	4.2	0%	0%	0%	0%
	4.3	0%	0%	0%	0%

Notes *** Covered with mortar and invisible to inspection.

9 month destructive coupon inspection

		Fort Stewart, GA				Duck, NC		
		Standard Steel	Galvanized Steel	Viterous Cotated Steel		Standard Steel	Galvanized Steel	Viterous Cotated Steel
Coupon # 1	Inside the Mortar [%]	50%	30%	0%		10%	10%	0%
	Outside the Mortar [%]	100%	100%	0%		100%	100%	5%*
	Corrosion Ingress [mm]	3	3	0		4.5	4.5	0
Coupon # 2	Inside the Mortar [%]	5%	10%	0%		50%	20%	0%
	Outside the Mortar [%]	100%	100%	5%*		100%	100%	5%*
	Corrosion Ingress [mm]	1	2	0		4.5	2	0
		Building 632				Building 635		
		Pintle		Wall Tie		Pintle		Wall Tie
Boroscope Site	1.1	0%		0%		0%		0%
	1.2	0%		0%		0%		0%
	1.3	0%		10%		0%		0%
	2.1	0%		10%		5%		5%
	2.2	0%		5%		0%		0%
	2.3	0%		0%		0%		5%
	3.1	0%		0%		0%		0%
	3.2	0%		0%		5%		5%
	3.3	***		0%		0%		5%
	4.1	0%		0%		5%		0%
	4.2	5%		0%		0%		5%
	4.3	0%		0%		0%		0%

Notes *Just the tip of the pintle started to corrode. *** Covered with mortar and invisible to inspection.

12 month destructive coupon inspection

		Ft. Stewart, GA				Duck, NC		
		Standard Steel	Galvanized Steel	Viterous Cotated Steel		Standard Steel	Galvanized Steel	Viterous Cotated Steel
Coupon # 1	Inside the Mortar [%]	20%	50%	0%		10%	5%	0%
	Outside the Mortar [%]	100%	100%	0%		100%	100%	5%*
	Corrosion Ingress [mm]	2	4	0		1	1.5	0
Coupon # 2	Inside the Mortar [%]	50%	50%	0%		50%	24%	0%
	Outside the Mortar [%]	100%	100%	0%		100%	100%	50%
	Corrosion Ingress [mm]	4.5	4.5	0		4.5	4.5	0
		Building 632				Building 635		
		Pintle		Wall Tie		Pintle		Wall Tie
Boroscope Site	1.1	0%		0%		0%		0%
	1.2	0%		0%		0%		0%
	1.3	5%		10%		0%		0%
	2.1	0%		10%		5%		5%
	2.2	0%		5%		0%		0%
	2.3	0%		0%		0%		5%
	3.1	0%		0%		0%		5%
	3.2	0%		0%		5%		5%
	3.3	***		0%		0%		5%
	4.1	0%		5%		5%		5%
	4.2	5%		0%		0%		5%
	4.3	0%		0%		0%		5%

Notes *Just the tip of the pintle started to corrode. *** Covered with mortar and invisible to inspection.

15 month destructive coupon inspection

		Ft. Stewart, GA				Duck, NC		
		Standard Steel	Galvanized Steel	Viterous Cotated Steel		Standard Steel	Galvanized Steel	Viterous Cotated Steel
Coupon # 1	Inside the Mortar [%]	10%	20%	0%		50%	75%	0%
	Outside the Mortar [%]	100%	100%	0%		100%	100%	5%*
	Corrosion Ingress [mm]	2	4.5	0		4.5	4.5	0
Coupon # 2	Inside the Mortar [%]	10%	20%	0%		50%	75%	0%
	Outside the Mortar [%]	100%	100%	0%		100%	100%	50%
	Corrosion Ingress [mm]	4.5	4.5	0		4.5	4.5	0
		Building 632				Building 635		
		Pintle		Wall Tie		Pintle		Wall Tie
Boroscope Site	1.1	0%		0%		0%		0%
	1.2	0%		0%		0%		0%
	1.3	5%		10%		0%		0%
	2.1	0%		10%		5%		5%
	2.2	0%		5%		0%		0%
	2.3	0%		0%		0%		5%
	3.1	0%		0%		0%		5%
	3.2	0%		0%		5%		5%
	3.3	***		0%		0%		5%
	4.1	0%		5%		**		**
	4.2	5%		0%		**		**
	4.3	0%		0%		**		**

Notes *Just the tip of the pintle started to corrode. **Location 4 at building 635 was unaccessible due to refurbishment construction. *** Covered with mortar and invisible to inspection.

18 month destructive coupon inspection

		Ft. Stewart, GA			Duck, NC		
		Standard Steel	Galvanized Steel	Viterous Cotated Steel	Standard Steel	Galvanized Steel	Viterous Cotated Steel
Coupon # 1	Inside the Mortar [%]	90%	5%	0%	75%	5%	0%
	Outside the Mortar [%]	100%	100%	0%	100%	100%	5%*
	Corrosion Ingress [mm]	4.5	0.25	0	4.5	0.25	0
Coupon # 2	Inside the Mortar [%]	75%	10%	0%	75%	5%	0%
	Outside the Mortar [%]	100%	100%	0%	100%	100%	0%
	Corrosion Ingress [mm]	4.5	2	0	4.5	0.25	0

		Building 632		Building 635	
		Pintle	Wall Tie	Pintle	Wall Tie
Boroscope Site	1.1	0%	0%	0%	0%
	1.2	0%	0%	0%	0%
	1.3	5%	10%	0%	0%
	2.1	0%	10%	5%	5%
	2.2	0%	5%	0%	0%
	2.3	0%	0%	0%	5%
	3.1	0%	0%	0%	5%
	3.2	0%	0%	5%	5%
	3.3	***	0%	0%	5%
	4.1	0%	5%	5%	5%
	4.2	5%	0%	0%	5%
	4.3	0%	0%	0%	5%

Notes *Just the tip of the pintle started to corrode. *** Covered with mortar and invisible to inspection.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
December 2016	Final Technical Report	

4. TITLE AND SUBTITLE
Demonstration and Validation of Reactive Vitreous Coatings to Prevent Corrosion of Steel Fixtures Attached to Masonry Walls: Final Report on Project F10-AR12

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
Corrosion Prevention and Control

6. AUTHOR(S)
Steven C. Sweeney, Christopher Olaes, and Darrell Skinner

5d. PROJECT NUMBER
CPC F10-AR12

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center
Construction Engineering Research Laboratory
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-16-23

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of the Secretary of Defense (OUSD(AT&L))
3090 Defense Pentagon
Washington, DC 20301-3090

10. SPONSOR/MONITOR'S ACRONYM(S)
OSD

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Masonry block and brick wall veneer construction, widely used on military installations, is subject to rapid deterioration when the ferrous hardware tying brick veneer to substrate corrodes prematurely. Corrosion of veneer-anchor hardware can compromise structural integrity and cause fracture and spalling of masonry materials. Because these building ties are concealed beneath the veneer, corrosion can proceed undetected until structural damage occurs. A new reactive silicate material that can be bonded to steel hardware with a layer of vitreous enamel, developed by the U.S. Army Engineer Research and Development Center, was evaluated for corrosion-protection performance in a demonstration project at Fort Stewart, GA. When fractured, this coating produces a self-healing reaction by formation of silicate hydration products that passivate any exposed steel surface. Steel anchors were coated with the vitreous enamel and then installed in sections of damaged brick veneer on buildings needing rehabilitation. Brick/block coupons were also fabricated using these anchors for exposure and ASTM E754 pullout-strength testing.

Results show that the enamel-coated ties were more corrosion resistant than both bare steel and galvanized ties used in the exposure specimens. Issues with coating coverage and flaking were noted, and implementation caveats are offered. The project return on investment was 3.31.

15. SUBJECT TERMS
Steel, Stress corrosion; Reinforced masonry; Protective coatings; Glass–ceramics; Corrosion and anti-corrosives

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